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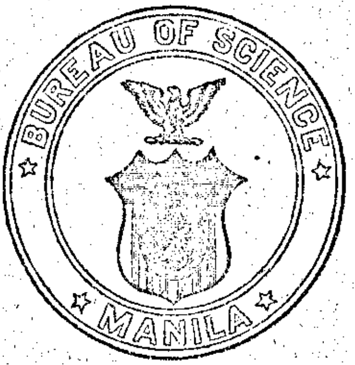

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CONTENTS

No. 1, July, 1919

[Issued December 23, 1919.]

Page.

COCKERELL, T. D. A. Philippine bees of the genus Nomia........ 1

COCKERELL, T. D. A. The metallic-colored halictine bees of the Philippine Islands........ 9

FUNKHOUSER, W. D. New records and species of Philippine Membracidæ........ 15
One plate.

SHUFELDT, R. W. Osteological and other notes on the monkey-eating eagle of the Philippines, Pithecophaga jefferyi Grant........ 31
Eleven plates.

UICHANCO, LEOPOLDO B. General facts in the biology of Philippine mound-building termites........ 59
Four plates.

BAKER, C. F. The Malayan Machærotinæ (Cercopidæ)........ 67
Three plates and one text figure.

COWLES, R. P. Habits of tropical Crustacea: III........ 81
One plate.

LEVINE, C. O. Milk produced in southern China........ 91
One plate.

WITT, J. C. The analysis of Portland cement raw mixture........ 107
Two text figures.

REVIEW........ 123

No. 2, August, 1919

[Issued December 29, 1919.]

MERRILL, E. D. On the application of the generic name Melodorum of Loureiro........ 125

CRAWFORD, DAVID L. The jumping plant lice of the Palæotropics and the South Pacific islands. Family Psyllidæ, or Chermidæ, Homoptera........ 139
Three plates and three text figures.

BAKER, C. F. The genus Krisna (Jassidæ)........ 209
Five plates.

No. 3, September. 1919

[Issued January 7, 1920.]

Page.

DEL ROSARIO, MARIANO V., and MARAÑON, JOAQUIN. The physico-chemical evaluation of tikitiki extract 221

MERRILL, E. D. Additional notes on the Kwangtung flora 225

KOORDERS, S. H. Notiz über Hoya imbricata Callery ex Decaisne und Hoya pseudomaxima Kds. in den Filipinen auf Grund von einigen Herbar-Exemplaren des Bureau of Science in Manila 263
Four plates.

COCKERELL, T. D. A. The black halictine bees of the Philippine Islands 269

BANKS, CHARLES S. The swarming of anopheline mosquitoes 283

BANKS, CHARLES S. The Philippine leaf-mining buprestids, one being new 289
Three plates.

BAKER, C. F. Notices of certain Fulgoroidea, II: The genus Trobolophya 301
Six text figures.

GROFF, ELIZABETH H. Soy-sauce manufacturing in Kwangtung, China 307
Seven plates.

REVIEWS 317

No. 4, October, 1919

[February 27, 1920.]

OSHIMA, MASAMITSU. Formosan termites and methods of preventing their damage 319
Thirteen plates and five text figures.

COCKERELL, T. D. A. A new scale insect on Rhizophora 385
One text figure.

DE LEON, WALFREDO. Balantidium haughwouti, new species, parasitic in the intestinal tract of Ampullaria species, a morphological study 389
One plate and five text figures.

No. 5, November, 1919

[March 1, 1920.]

BEZZI, M. Fruit flies of the genus Dacus sensu latiore (Diptera) from the Philippine Islands 411
Two plates.

FLEUTIAUX, ED. Melasidæ nouveaux (Coléoptères) recoltés par C. F. Baker 445

CAÑIZARES, MIGUEL. Some abnormalities of the vertebral artery 451
One plate and five text figures.

PERKINS, GRANVILLE A. The rancidity of Philippine coconut oil 463

BURKILL, I. H. The genus Gordonia in the Philippine Islands 475

REINKING, O. A. Higher Basidiomycetes from the Philippines and their hosts, I 479

REVIEW 491

No. 6, December, 1919

[March 30, 1920.]

Page.

SHAW, WALTER R. Campbellosphaera, a genus of the Volvocaceae.. 493
Two plates and one text figure.

MUIR, FREDERICK. Some Malayan Delphacidæ (Homoptera)........... 521
One plate.

WORCESTER, DEAN C. A nesting place of Micropus subfurcatus in Mindoro 533

HAUGHWOUT, FRANK G. A method for labeling slides used in routine stool examinations.. 535
One text figure.

MERRILL, E. D. Additions to the flora of Guam.............................. 539

SCHULTZE, W. Seventh contribution to the Coleoptera fauna of the Philippines 545
One text figure.

HAUGHWOUT, FRANK G., LANTIN, PEDRO T., and FERNANDEZ, RICARDO. A case of acute mania associated with Plasmodium vivax infection 563
One text figure.

REVIEWS 571

INDEX 575

THE PHILIPPINE
JOURNAL OF SCIENCE

VOL. XV JULY, 1919 No. 1

PHILIPPINE BEES OF THE GENUS NOMIA

By T. D. A. COCKERELL
Of the University of Colorado

The andrenid genus *Nomia* is widely distributed over the world, but is much more numerous in species in the Eastern than in the Western hemisphere. The species show such diverse characters that authors have at different times proposed to divide the genus into several genera and subgenera. It is doubtfully expedient, however, to recognize more than one genus, though most of the names proposed may properly be used in a subgeneric sense. The type of the genus, as Meade-Waldo has shown, is the Asiatic *Nomia curvipes* of Fabricius. This has colored tegumentary bands on abdomen, postscutellum unarmed, and the hind femora of the male greatly swollen and sharply toothed beneath. It may be considered typical of a group which in the Philippine fauna includes *N. thoracica, N. longitarsis, N. lusoria, N. strigata,* and *N. iridescens;* but none of these has the hind femora of the male as in *curvipes.* In *N. thoracica* these femora are swollen, but not toothed beneath.

Hoplonomia Ashmead resembles true *Nomia,* but has a bidentate process, or two teeth, on the postscutellum. The type is *N. quadrifasciata,* a Philippine species.

The following key will facilitate the separation of the Philippine species:

Key to the Philippine species of Nomia.

Abdomen pale red (Sulu Island)........ dimidiata Vachal.
Abdomen not red........ 1.
1. Antennæ and legs entirely dull ferruginous; female, 12.5 millimeters long (Palawan)........ philippina Vachal.
Antennæ and legs otherwise colored; or, if reddish, smaller species.... 2.
2. Postscutellum bidentate or bispinose........ 3.
Postscutellum unarmed........ 4.
3. Male with hind tibiæ, except a large black spot behind, and hind tarsi, yellowish........ quadrifasciata (Ashmead).
Male with hind tibiæ, except apical process, and hind basitarsi, black or brown........ quadrifasciata notha Cockerell.

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4. Abdomen with tegumentary bands, not covered with hair .... 5.
Abdomen without such bands, though the hind margins of segments may be reddish or testaceous .... 7.
5. Bands white .... thoracica stantoni (Ashmead).
Bands yellowish or red .... longitarsis Cockerell.
Bands green, sometimes suffused with red .... 6.
6. First abdominal segment without a band .... iridescens Smith.
First abdominal segment with a band .... strigata (Fabricius).
Like *strigata*, but hind legs modified (see description). lusoria sp. nov.
7. Abdomen clavate (males) .... 8.
Abdomen not clavate .... 10.
8. Fifth ventral segment of abdomen of male with two red spots bearing black prominences .... elongatula Cockerell.
Fifth ventral segment not so .... 9.
9. First abdominal segment of male narrow and little punctured. lautula sp. nov.
First abdominal segment broader and more distinctly punctured; larger species .... levicauda Cockerell.
10. Males .... 11.
Females .... 12.
11. Hind basitarsi pallid; hind femora enormously swollen. goniognatha sp. nov.
Hind basitarsi dark .... philippinensis (Friese).
12. Rather large species, quite robust, with coarse punctures on mesothorax and excessively fine and dense punctures on abdomen; hind margin of first abdominal segment black .... recessa sp. nov.
Smaller species, with other characters .... 13.
13. Stigma small; area of metathorax almost or quite linear. philippinensis (Friese).
Stigma large; abdomen of male clavate .... 14.
14. Second abdominal segment smooth and shining .... levicauda sp. nov.
Second abdominal segment rough and punctured .... palavanica Cockerell.

Nomia quadrifasciata (Ashmead).

Hoplonomia quadrifasciata ASHMEAD, ♂ (as "♀"), Journ. N. Y. Ent. Soc. 12 (1904) 4.
Nomia quadrifasciata (ASHMEAD) COCKERELL, Entomologist 48 (1915) 177.

LUZON, Manila (*W. A. Stanton*). MINDANAO, Dapitan (*Baker*). The Dapitan specimen agrees with Ashmead's account, but is I think certainly only a variation of the commoner form, *Nomia notha*. Unless additional material from Manila shows better distinctive characters, I must conclude that there is only one distinct species involved.

Nomia quadrifasciata notha (Cockerell ined.).

Nomia notha COCKERELL, Entomologist 51 (1918) 112.
Hoplonomia quadrifasciata ASHMEAD, ♂ (not "♀"), Journ. N. Y. Ent. Soc. 12 (1904) 4.

Nomia incerta "GRIBODO" COCKERELL, Entomologist 48 (1915) 177 (not *incerta* Gribodo).

The receipt of genuine *Nomia incerta* from Java (Mount Salak, 2,500 feet, 3. 7. 09, *Bryant and Palmer*, United States National Museum), shows that this species (female) has the mesothorax with punctures of two sizes and the lobes of the postscutellar process very obtuse. The Philippine insect is clearly distinct, having the mesothorax with strong practically uniform punctures, and the lobes of the postscutellar process long and acute. The type, from Los Baños, is a female having the three abdominal bands apple green suffused with vermilion. All my material is from Baker.

LUZON, Manila (*Stanton*): Laguna Province, Los Baños and Mount Maquiling: Tayabas Province, Mount Banahao. MINDANAO, Dapitan and Davao. LEYTE, Tacloban. PALAWAN, Puerto Princesa. Related to *N. simplicipes* Friese.[1]

The following varieties look very distinct, but do not represent true races:

Nomia quadrifasciata var. aurantia var. nov.

Female.—Like *Nomia notha,* but abdominal bands rich orange, slightly tinged with apple green.

LUZON, Laguna Province, Mount Maquiling (*Baker*). Two specimens; one is *Baker 7469.*

Nomia quadrifasciata var. viridans var. nov.

Female.—Like *Nomia notha,* but abdominal bands very bright emerald green.

LUZON, Laguna Province, Los Baños (*Baker*).

Nomia thoracica stantoni (Ashmead).

Paranomia stantoni ASHMEAD, Journ. N. Y. Ent. Soc. 12 (1904) 4.
Nomia thoracica stantoni (ASHMEAD) COCKERELL, Entomologist 48 (1915) 177.

LUZON, Manila (*Stanton*): Laguna Province, Los Baños and Mount Maquiling (*Baker*). An insular race, smaller than typical *N. thoracica* Smith.

---

[1] *Nomia simplicipes* was described from Kaulun, near Hongkong. The male has the first segment of the abdomen green banded, and may not be conspecific with the female. As the specific name is derived from a character of the male, I herewith designate that as the type. This male is readily separated from *N. notha;* but a female *simplicipes* (agreeing with Friese's description) from Trong, Lower Siam, January–February, 1899 (W. L. Abbott; United States National Museum), is essentially like *N. notha,* except that the depressed part of the second abdominal segment is much broader (anteroposteriorly) in the middle.

Nomia longitarsis Cockerell.

Nomia longitarsis COCKERELL, Entomologist 49 (1916) 158.

The type is a male. The female (Mount Maquiling) is similar, with the usual sexual differences, the mesothorax more finely punctured, and the abdomen with much shallower and more feeble punctures. The stigma in both sexes is ferruginous.

LUZON, Laguna Province, Mount Maquiling (*Baker*).

Nomia longitarsis eboris var. nov.

Male and female.—Stigma black or reddish black; abdominal bands (except the first in female) clear opaque ivory color.

LUZON, Nueva Vizcaya Province, Imugan, male (type): Benguet Subprovince, Baguio, female. Both from Baker. Probably a subspecies, but without strong characters.

Nomia strigata (Fabricius).

Andrena strigata FABRICIUS, Ent. Syst. 2 (1793) 311.
Nomia strigata LEPELETIER, Hist. Nat. Ins. Hymén. 2 (1841) 291.
Nomia iridescens "SMITH," COCKERELL, Entomologist 48 (1915) 177 (not *iridescens* Smith).

I had formerly supposed[2] that the male of *Nomia iridescens* differed from the female in having the first five abdominal segments with colored bands, but I now find that there are males and females with (*strigata*) and without (*iridescens*) the band on first segment. Some specimens of *N. strigata*, as is usual in this group of *Nomia*, have bands which fail to assume the proper color, but then these bands are pallid or reddish, very different from the opaque black hind margin of the first segment in *iridescens*. It must be stated, however, that *strigata* and *iridescens* are extremely closely allied, and it is by no means certain that they are not forms of a single species. *Nomia quadridentata* Smith is based on a female that is evidently *strigata* and on a male of the *N. ellioti* group. The first and fullest description is that of the female, which is herewith designated as the type.

PALAWAN, Puerto Princesa. MINDANAO, Davao. NEGROS, Cuernos Mountains. All from Baker. The Philippine insect agrees with that from Java (Depok, Pelaboeam, Ratoe, Buitenzorg), collected by Bryant and Palmer (United States National Museum).

Nomia strigata var. ridleyi (Cockerell).

Nomia iridescens var. *ridleyi* COCKERELL, Ann. & Mag. Nat. Hist. VIII 5 (1910) 503.

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[2] Ann. & Mag. Nat. Hist. VIII 5 (1910) 503.

MINDANAO, Davao (*Baker 7468*). Described from Singapore and also collected by Bryant and Palmer in Java (Buitenzorg, March, 1909; Depok). It is a color variety, doubtless alternating in Mendelian fashion with the typical form.

Nomia iridescens Smith.

Nomia iridescens SMITH, Journ. Proc. Linn. Soc. London, Zool. 2 (1857) 43.

LUZON, Laguna Province, Los Baños and Mount Maquiling. MINDANAO, Butuan and Davao. All from Baker. I have a female from F. Smith's collection, and the Philippine form agrees with it.

Nomia iridescens var. rhodochlora var. nov.

Male and female.—Abdominal bands bright yellowish green, suffused with vermilion.

MINDANAO, Dapitan (*Baker 7466*), male. NEGROS, Cuernos Mountains (*Baker*), female. The type locality is Dapitan.

Nomia lusoria sp. nov.

Male.—Like *N. strigata ridleyi*, but with third (as well as following) antennal joints clear red beneath; hind femora swollen, the upper side strongly convex; hind tibiæ greatly enlarged apically, the end reddish yellow, the inner side flattened and expanded apically, its margin broadly rounded and expanded; hind basitarsi pale reddish dusky apically.

PALAWAN, Puerto Princesa (from *Baker*).

Nomia elongatula Cockerell.

Nomia elongatula COCKERELL, Entomologist 48 (1915) 178.

LUZON, Laguna Province, Los Baños (type locality) and Mount Maquiling: Benguet Subprovince, Baguio. LEYTE, Tacloban. MINDANAO, Iligan. PALAWAN, Puerto Princesa. All from Baker.

Nomia levicauda sp. nov.

Nomia elongata "FRIESE," COCKERELL, Entomologist 48 (1915) 178 (not *N. elongata* Friese).

Finding that this group of *Nomia* included several distinct species, recognizable by the characters of the male abdomen, I was led to reëxamine the species from Luzon which Friese had identified with his *N. elongata*, described from Java. Evidently the Philippine species is distinct, for although Friese's description of the male is brief, he states that the fifth ventral abdominal segment is bare, whereas in our insect it is hairy right across. The female is very similar to that of *N. philippinensis*, but the area of metathorax is rather broad (anteroposteriorly) and irregularly plicate, and the abdomen is shiny. The stigma is very much larger than that of *philippinensis* and is of the same general type as that of *N. palavanica*, but dusky or with a dusky margin. The second abdominal segment is smooth and shining, whereas in *palavanica* it is rough and punctured.

LUZON, Laguna Province, Los Baños (type locality): Benguet Subprovince, Baguio. MINDANAO, Zamboanga. The females come from the following places: LUZON, Laguna Province, Mount Maquiling: Benguet Subprovince, Baguio. MINDANAO, Davao and Iligan. All from Baker. The series of females may include examples of the next species, which is perhaps not clearly separable in that sex.

Nomia lautula sp. nov.

Male.—Length, about 6 millimeters; slender, with the basitarsi cream color, their apices and the small joints of tarsi ferruginous; abdomen clavate, slender basally; the hind margins of segments with pale ocherous-tinted hair bands; face with pale golden hair; stigma large, dusky reddish. This species is so similar to *N. levicauda* that I thought it might be only a race, but it is certainly a distinct species, differing by the narrow and little-punctured first abdominal segment, the very densely punctured mesothorax, and especially the fifth ventral segment of abdomen, which has a pair of separate rounded elevations, covered with short, dark-tipped, more or less bifid bristles, instead of being hairy right across as in *N. levicauda.*

MINDANAO, Davao (*Baker*; two bear the numbers *7470*, *7471*).

Nomia palavanica Cockerell.

Nomia palavanica COCKERELL, Entomologist 48 (1915) 178; 49 (1916) 158.

PALAWAN, Puerto Princesa (*Baker 3848*).

Nomia philippinensis (Friese).

Nomia takauensis philippinensis FRIESE, COCKERELL, Entomologist 48 (1915) 178.

LUZON, Laguna Province, Los Baños (type locality) and Mount Maquiling: Benguet Subprovince, Baguio: Tayabas Province, Malinao and Mount Banahao. MINDANAO, Davao. All from Baker.

Nomia goniognatha sp. nov.

Male.—Length, 7 to 8 millimeters; black, with the knees, tibiæ at apex, and tarsi except apex, yellowish ferruginous; pubescence pale ocherous, the mesothorax and scutellum with short, fulvous, mosslike hair; tongue very slender; eyes brown, strongly converging below; mandibles broad, pale testaceous, with the apex piceous and the swollen inner side of base broadly black, while the lower margin, beyond the middle, is conspicuously angular; vertex minutely rugose-punctate; area of metathorax very small, with five oblique striæ; tegulæ reddish testaceous, with piceous base; wings dusky, stigma testaceous, not large; hind femora enormously swollen, helmet-shaped; hind tibiæ short and broad, curved basally; abdomen finely punctured, the segments with pale fulvous hair bands; fourth ventral segment emarginate, with a median keel on a ferruginous band; fifth ventral with a strong dark keel produced to a claviform apex. The flagellum is bright ferruginous beneath, except at base and apex.

MINDANAO, Davao (from *Baker*).

In Bingham's table of Indian species this falls nearest to *N. aurifrons* Smith, to which are allied the later-described *N. aureobalteata* Cameron and *N. kangræ* Nurse. *Nomia aureobalteata* has a large metathoracic area, different legs, etc. *Nomia aurifrons* has testaceous legs. *Nomia kangræ* also differs in the legs and in other ways. The hair on the thorax in *N. goniognatha* recalls the much larger *N. thoracica* or the Indian *N. ardjuna* Cockerell.

Nomia recessa sp. nov.

Female.—Length, about 9 millimeters or rather more; robust, black, with fine pale cinereous to white (on cheeks) hair, on mesothorax and scutellum thin and mainly fuscous, on vertex with a pale golden tint, on inner side of tarsi orange-ferruginous; hind tibiæ with hair mainly yellowish white, but on outer face dark fuscous; hind margin of first abdominal segment black, of the others broadly testaceous; no hair bands on apical margins of segments, but third segment with an even white basal fringe beneath the testaceous margin of second. Eyes dark reddish; mandibles dark reddish, black at base; antennæ black, the flagellum red apically, especially beneath; face broad, with thin cinereous hair; mesothorax densely and strongly punctured, but shining between the punctures; scutellum shining, with large well-separated punctures; area of metathorax very small, but with strong ridges; tegulæ piceous with pallid margins; wings somewhat dusky, especially the apical marginal area; stigma dark castaneous; second submarginal cell receiving first recurrent nervure much beyond middle; legs entirely dark; abdomen dull, with excessively fine punctures; venter with reddish fulvous hair.

LUZON, Laguna Province, Mount Maquiling (*Baker*). Somewhat related to the Indian *N. basalis* Smith, but differing in the pubescence and the color of the wings.

Nomia dimidiata Vachal.

Nomia dimidiata VACHAL, Miscellanea Entomologica 5 (1897) 8 of separate.

SULU ISLAND. One female in collection of Gribodo. Length, 6.5 millimeters.

Nomia philippina Vachal.

Nomia philippina VACHAL, Miscellanea Entomologica 5 (1897) 7 of separate.

PALAWAN. One female in collection of Vachal. The author suggested that it was possibly a variety of *N. buddha* Westwood. The latter he had from Perak.

THE METALLIC-COLORED HALICTINE BEES OF THE PHILIPPINE ISLANDS

By T. D. A. Cockerell

Of the University of Colorado

The subfamily Halictinæ, numerously represented in almost every part of the world, contains groups of species in which the surface of the body is black, brown, or yellowish, and others in which portions, at least, are metallic green or blue. The large genus *Halictus,* as generally understood, contains both metallic and nonmetallic species. In the Holarctic Region, Robertson has separated the metallic species as genera *Chloralictus* Robertson and *Seladonia* Robertson. He also recognizes, in North America, genera *Dialictus* Robertson (with only two submarginal cells) and *Paralictus* Robertson. How many such genera should be segregated from the old *Halictus,* it is hard to decide; and certainly the Robertsonian groups are less distinct than the genera commonly recognized among bees. The French entomologist Vachal went as far from current usage on the other side and not only refused to accept Robertson's genera, but threw into *Halictus* such genera as *Augochlora* and *Agapostemon,* almost universally considered distinct. The genus *Nomioides* Schenck, placed as a subgenus of *Halictus* by Dalla Torre, must be considered a distinct genus. Its members are small, usually with conspicuous yellow markings, almost perfectly imitating the American panurgine genus *Perdita.* Yet the venation is like that of *Halictus,* except that the marginal cell is narrowly truncate at the end. These bees are so unlike the species of *Halictus* that Cameron described several of them in *Ceratina.* Thus my *Nomioides comberi* from India must be called *N. punjabensis* (Cam.); for Meade-Waldo, on examining Cameron's types, found that his *Ceratina punjabensis,* published about four years earlier, was in fact my insect. It also appears that *Ceratina cerea* Nurse is to be called *Nomioides pulchella* Schenck or, according to the synonymy indicated by Alfken, *N. parvula* (Fabricius).

Genus **NOMIOIDES** Schenck

Mesothorax green.. 1.
Mesothorax steel blue, highly polished.. 2.
1. Larger; abdomen with four entire yellow bands; mesothorax duller.. dapitanellus Cockerell.
Smaller; abdomen with four (varying to two) lateral yellow marks, representing two widely interrupted bands; mesothorax more shining.. valdezi Cockerell.

2. Larger (length, about 6 millimeters); abdomen black, without light markings........ melanogaster Cockerell.
   Smaller; abdomen marked with yellow........ valdezi Cockerell.

Nomioides dapitanellus Cockerell.

Nomioides dapitanellus COCKERELL, Entomologist 48 (1915) 107.

MINDANAO, Dapitan (*Baker 3161*).

Nomioides valdezi Cockerell.

Nomioides valdezi COCKERELL, Ann. & Mag. Nat. Hist. VIII 16 (1915) 487.

MINDANAO, Cagayan (*Baker 3670*), type locality. Also PALAWAN, Puerto Princesa (*Baker 8065*). In the Palawan males the mesothorax is usually steel blue, as in the type, but occasionally it is shining green. There are two females from Palawan. They are about 5.2 millimeters long; mesothorax green; scutellum with two large yellow spots; postscutellum with a yellow bar; abdomen with large oblique cuneiform yellow marks at sides of second and third segments.

Nomioides melanogaster Cockerell.

Nomioides melanogaster COCKERELL, Ann. & Mag. Nat. Hist. VIII 16 (1915) 487.

MINDANAO, Dapitan (*Baker 3162*).

Genus HALICTUS Latreille

Females........ 1.
Males........ 4.
1. Mesothorax shining green; abdomen more or less purplish, green at base........ subpurpureus sp. nov.
   Mesothorax dullish or granular or abdomen not purplish........ 2.
2. Abdomen bright green........ 3.
   Abdomen bluish green to olive green, but knees red; scape red at base. adonidiæ sp. nov.
   Abdomen dark, at most slightly greenish........ pervarians sp. nov.
3. All the tibiæ red; scape red at base........ taclobanensis Cockerell.
   Tibiæ black; scape all black........ imuganensis sp. nov.
4. Abdomen black, slender........ pervarians sp. nov.
   Abdomen metallic, not slender........ 5.
5. Abdomen blue-green; legs mainly dark........ cyanescens sp. nov.
   Abdomen yellowish green; tibiæ and tarsi clear ferruginous; base of scape ferruginous........ taclobanensis Cockerell.

Halictus taclobanensis Cockerell.

Halictus taclobanensis COCKERELL, Ann. & Mag. Nat. Hist. VIII 16 (1915) 488.

LEYTE, Tacloban (*Baker 3672*), type locality. LUZON, Mount Maquiling (*Baker*), female. MINDANAO, Davao (*Baker 8067*), male; Cagayan (*Baker*), male. The male has the form of a female, as in certain Australian species, and the only conspicuous differences are in the longer antennæ and the caudal end of the abdomen.

Halictus subpurpureus sp. nov.

Female.—Length, about 6.5 millimeters; head very dark greenish, almost black; mandibles rufous at apex; clypeus feebly and sparsely punctured; supraclypeal area purplish; front with a sericeous luster; antennæ entirely black; mesothorax yellowish green, shining but not polished, without evident punctures; scutellum and hind margin of mesothorax glaucous green; area of metathorax large, with a very fine irregular reticulation; posterior truncation not sharply margined at sides; tegulæ dark brown; wings dusky, stigma black; first recurrent nervure meeting second transverse cubital; third submarginal cell narrow, quadrate, shaped nearly like the second; legs black; abdomen dorsally shining without bands and without evident punctures, the general color black, but the base greenish and the middle segments conspicuously suffused with purple; venter with large tufts of pale ocherous hair at the sides of the segments.

LUZON, Baguio, Benguet (*Baker*). Related to *H. pervarians*, but larger, with mesothorax more shining, and abdomen suffused with purple.

Halictus pervarians sp. nov.

Female.—Length, about 5.5 millimeters; head rather small, glaucous green; antennæ black; mesothorax and scutellum yellowish green, shining but not polished, without evident punctures; mesothorax with a median longitudinal depression; area of metathorax appearing dull and granular under a lens, the broadly rounded margin shining; tegulæ pale brown, dark at base; pleura bluish green; wings faintly dusky; stigma black; first recurrent nervure meeting second transverse cubital; third submarginal cell short; outer nervures of third submarginal and outer discoidal cells weakened; legs black; abdomen without bands, black with a greenish or brassy tint. Ventral segments of abdomen with lateral ocherous tufts as in *H. subpurpureus*.

Variety *a*. Front peacock green and supraclypeal area purple.

Variety *b*. Length, about 5 millimeters; tegulæ pale testaceous; tarsi ferruginous; stigma brown.

Variety *c*. Flagellum reddish beneath; mesothorax and scutellum very dark green; area of metathorax dark bluish. Stigma black as in the typical form.

Male.—Antennæ very long, black; face green; abdomen slender, black; tarsi, and anterior tibiæ in front, ferruginous. A male from Mount Banahao is considerably larger than one from Mount Maquiling.

LUZON, Mount Maquiling (*Baker*), type and varieties *a* and *b;* Imugan (*Baker*), variety *c;* Mount Banahao (*Baker*), male. Very variable, but apparently all one species. I have nine specimens before me.

Halictus imuganensis sp. nov.

Female.—Length, about 7 millimeters; bright golden green, the clypeus, mesothorax, and scutellum variably suffused with coppery red, or entirely green, or the clypeus peacock green; mandibles obscure reddish; face, front, mesothorax, and scutellum with a roughened granular surface; antennæ black; area of metathorax shining, with strong, irregular plicæ, forming a coarse irregular network; posterior truncation sharply defined at sides; thorax above with thin ocherous hair; tegulæ rufopiceous; wings very faintly dusky; stigma black; second submarginal cell large and broad, receiving first recurrent nervure at its apical corner; outer transverse cubital and recurrent nervures weakened; legs black; abdomen shining, without bands; a well-developed ventral scopa.

LUZON, Imugan (*Baker*), type locality. Mount Banahao (*Baker*): Baguio, Benguet (*Baker*). Five specimens are before me. Allied to *H. taclobanensis.*

Halictus adonidiæ sp. nov.

Female.—Length, about 6.5 millimeters; shining green, with dark tarsi, tegulæ rufotestaceous, and basal half of scape red. Closely allied to *H. imuganensis* Cockerell, differing in the color of scape, the bluish green (not brassy green) abdomen, the broader head, the scutellum and posterior half of mesothorax brilliantly shining, and the paler (brownish) stigma.

LUZON, Manila, Malate (*R. C. McGregor*), October 27, 1918, at flowers of *Adonidia merrillii* Beccari.

Halictus cyanescens sp. nov.

Male.—Length, a little over 5 millimeters; head, thorax, and abdomen blue-green; face and front, including clypeus, dull and granular; antennæ black; mesothorax granular; area of metathorax irregularly reticulate; posterior truncation sharply defined at sides; tegulæ testaceous; wings very faintly dusky, stigma piceous; legs black; tarsi reddened apically; abdomen shining, without bands.

LUZON, Mount Banahao (*Baker*), two specimens. Very close to *H. imuganensis* and *H. taclobanensis*, having the robust form of a female in the male sex. The sexes of *H. taclobanensis* are colored alike, so I suppose the present insect to be distinct from *H. imuganensis*, from which it principally differs by being much smaller and quite differently colored.

The green *Halicti* of the Philippines fall into two very different groups or subgenera; one group consists of *H. subpurpureus* and *H. pervarians*, and the second consists of the other three species. The first is *Chloralictus* of Robertson; the second, with males resembling the females, may form a new subgenus **Homalictus**; type, *H. taclobanensis*.

NEW RECORDS AND SPECIES OF PHILIPPINE MEMBRACIDÆ

By W. D. FUNKHOUSER

Of the Zoölogical Laboratory, University of Kentucky

ONE PLATE

Since the publication of a revised checklist of the Membracidæ described from the Philippine Islands[1] some very interesting new species and records have been received from Mr. R. C. McGregor, of the Bureau of Science, Manila, and from Prof. C. F. Baker, of the College of Agriculture, Los Baños, P. I., the study of which throws considerable light on the distribution and the range of certain species that are extremely rare.

Most of the material on which this paper is based was collected by Mr. McGregor in Antique Province, Panay Island, and on the small island of Batbatan, just off the west coast of Panay. Other valuable records received from Mr. McGregor were secured in Laguna and Rizal Provinces, Luzon Island, a few of them from the immediate environs of Manila. Mr. McGregor has secured the first data to be published on the food plants of a number of the species and has also collected for several species the nymphal forms, which have never been recorded. I am greatly indebted to Mr. McGregor and again to Professor Baker for the opportunity of studying this very interesting material.

Centrochares horrificus Westw. Plate I, fig. 1.

Add: *Habitat.*—PANAY, Antique Province, Culasi (*McGregor*).
Host.—*Acalypha stipulacea* Klotz.

A good series of nineteen specimens collected at Culasi by Mr. McGregor in 1918. Six males and six females were taken May 18, in the forest at an altitude of about 700 meters; one male and four females, on May 27, on shoots from a stub of *Acalypha stipulacea;* one female, on May 29, and one female, on June 15.

In spite of the long series of specimens of this species from the Islands which I have seen at various times, I am unable to recognize specific differences sufficient to admit *C. posticus* Buckton and *C. bucktoni* Distant as distinct species. It has already been noted in previous papers[2] that *C. horrificus* shows considerable variation in size and in color, some of which conforms to Buckton's descriptions and figures for his supposed new species. I am still unconvinced that they are distinct.

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[1] Funkhouser, W. D., Notes on the Philippine Membracidæ, *Philip. Journ. Sci.* § D 13 (1918) 21-38.

In addition to the adults recorded above, Mr. McGregor sends a nymph of this species, which is apparently in the third or fourth instar, taken with the adults at Culasi on May 27 and sent to me on a section of the leaf on which it was captured.

Since the immature form (Plate I, fig. 1) of this insect has never been noted in literature, it seems advisable to include a brief description, as follows:

Entirely yellow (specimen preserved in alcohol); length, 4 millimeters; width between humeral tubercles, 1.5; height from apex of clypeus to top of metopidium, 2.8; roughly sculptured; densely pubescent; pronotum showing a suprahumeral tubercle on each side and a median dorsal posterior process which extends backward over the mesothorax but does not reach metathorax.

Head longer than broad, roughly pubescent, without tubercles, ocelli not visible, eyes large.

Thorax distinctly divided into segments; prothorax rough, densely pubescent, metopidium perpendicular, pronotum showing two strong tubercles representing the suprahumeral horns, posterior process extending backward over mesonotum but not reaching metanotum; mesonotum with a small tubercle on each side of median line; wing pads well developed, extending to first abdominal segment; entire thorax yellowish and densely pubescent with grayish hairs.

Abdomen showing nine segments, each segment slightly nodulate above with tufts of bristly hairs and extended ventrocaudad at lateral margin with edges of segment pilose; anal tube short, blunt, slightly upraised.

Legs flattened, first two pairs somewhat foliaceous, very densely pubescent; tarsi well developed, three joints distinct; claws swollen and heavy.

Judging from the development of the pronotal tubercles, the length of the wing pads, and the invisible ocelli, this nymph is in its third instar. It was attached by the first pair of legs to the midrib of the leaf in a position for molting.

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[2] Funkhouser, Philip. Journ. Sci. § D 10 (1915) 370 and 13 (1918) 23.

Pyrgonota bifoliata Westw.

Add: *Habitat.*—PANAY, Antique Province, Culasi (*McGregor*).

Eighteen specimens collected at Culasi by Mr. McGregor in 1918. Two specimens were taken in the forest at an altitude of about 700 meters on May 18, one on May 24, three on May 29, one on May 30, ten on June 15, and one on June 20.

This species has often been figured to represent the grotesque and unusual development of the pronotum in the Membracidæ and usually stands as a "show species" in museums. It is unusual to find so large a series as the present material offers.

Pyrgonota bifurca Stål.

Add: *Habitat.*—LUZON, Baguio, Benguet Subprovince (*Baker*).

This is the first record of this species since its original description by Stål in 1870.[3] Stål's description is very detailed and closely fits the single specimen from Baguio. The lateral carina on the posterior process of the pronotum is not as distinct as might be expected from the original description but is rather irregular throughout and obsolete at the extremity. In all other respects, however, the characters seem identical. The specimen before me bears Professor Baker's duplicate No. 7657.

Pyrgonota semperi Stål. Plate I, figs. 2 and 3.

Add: *Habitat.*—PANAY, Antique Province, Culasi (*McGregor*).
Host.—*Acalypha stipulacea* Klotz.

It has been a great pleasure to be able at last to recognize this species from three specimens collected by Mr. McGregor at Culasi—one on May 28, one on May 29, and one on June 30, 1918.

The species has never been recognized since its original description;[4] this description is very meager, being merely four lines of Latin comparing the type with *P. bifurca*. However, I feel confident that the Culasi material represents the insect which Stål described. It has the pale marking on the posterior process which is the chief distinctive character according to Stål, and the measurements exactly agree with those of the type. On account of the fact that the original description is so brief and the fact that the species has never been figured, I am including a more complete list of its characters as follows:

Very dark brown, almost black, coarsely and evenly punctate, sparingly pubescent with grayish hairs; pronotal horn long, erect, subcylindrical, narrowing toward the apex, apex forked, the prongs of the fork twisted and broadly foliaceous; posterior process long, slender, slightly elevated behind the middle, marked with a pale median line for basal two-thirds; tegmina entirely very dark brown or black. (Cf. Stål: "processu postico thoracis ante medium macula pallescente notato, pone medium quam anterius altiore, tegminibusque totis piceis.")[5]

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[3] Oef. Kongl. Vet.-Akad. Forhandl. No. 7 (1870) 731.

[4] Loc. cit.

Head longer than broad, foliaceous, roughly sculptured, dark brown, coarsely punctate, finely pubescent; base sinuate, highest on either side of median suture; sutures distinct, elevated; eyes prominent, brown; ocelli very prominent, opalescent, shining, much farther from each other than from the eyes and situated well above a line drawn through centers of eyes; inferior margins of genæ sinuate, foliaceous, sloping downward abruptly to clypeus; clypeus foliaceous, distinctly trilobed, two smooth longitudinal striæ down middle, finely punctate, sparingly pubescent, tip pilose.

Pronotum uniform dark brown or black except narrow yellowish line on basal two-thirds of posterior process, roughly punctate, sparingly pubescent with grayish hairs on upper parts, very densely pubescent and tomentose just before humeral angles; humeral angles not prominent, obtuse; anterior pronotal horn erect, long, slender, turriculate, heavy at base, gradually becoming narrower toward apex, bearing a distinct median carina in front, two or three irregular lateral ridges and a sharp posterior ridge which is strongly toothed, the teeth becoming smaller and closer together as they approach the posterior process, apex of horn forked, forks bent backward, with a slight extension of the median column between the two prongs of the forks; prongs of the fork as seen from the front widely separated at their bases, then approaching each other and nearly touching at their tips, much compressed laterally below, somewhat twisted and triquerate at apex, apical ends obliquely and sinuately truncate; posterior process long, slender, sinuate, highest behind middle, basal two-thirds marked with narrow yellowish vitta, sharply carinate and denticulate above, tip depressed and extending somewhat beyond lateral angles of tegmina.

Tegmina opaque, dark brown or black, strongly punctate and coriaceous in basal and costal regions, a very small pale spot at internal angles, tips long and acute, five apical and three discoidal areas.

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[5] Loc. cit.

Sides of mesothorax and metathorax toothed, densely tomentose with white hairs; undersurface of body and abdomen brown.

Legs entirely yellow; tibiæ flattened and minutely spined; claws ferruginous.

Length, including tegmina, 7 millimeters; width between humeral angles, 2; height of pronotal horn from humeral angles to tips, 10.

Leptocentrus reponens Walk.

Add: *Habitat.*—LUZON, Manila: Rizal Province, Montalban: Laguna Province, Paete. PANAY, Antique Province, Tibiao, Culasi, and Lipata. (*McGregor.*)

Host.—*Blumea balsamifera* (L.) DC.; *Semecarpus cuneiformis* Blanco; *Acalypha wilkesiana* Muell.-Arg.; *Mallotus moluccanus* (L.) Muell.-Arg.; *Hibiscus rosa-sinensis* L.

An excellent series with records of the host plants, collected as follows: Two from Montalban taken February 22, 1918, on *Blumea balsamifera* and *Semecarpus cuneiformis;* one from Manila, February 1, 1917; three from Manila, February 5, 1917, on *Mallotus moluccanus;* one from Manila, February 5, 1917, on *Acalypha wilkesiana;* one from Manila, February 10, 1917, on *Hibiscus rosa-sinensis;* one from Lipata, July 9, 1918, on "a spiny shrub;" two from Paete, March 6 and 13, 1917; five from Tibiao, May 14, 1918; four from Culasi taken in the forest at about 700 meters' elevation on May 18, 1918; two from Culasi, May 20, 1918; one from Culasi, June 3, 1918; one from Culasi, June 19, 1918, and two from Culasi, July 24, 1918.

The above data for hosts are the first ever recorded for this species, and all of the localities are new.

Mr. McGregor's field notes record the interesting fact that this species was not attended by ants.

Leptocentrus leucaspis Walk.

Add: *Habitat.*—Antique Province, Batbatan Island (*McGregor*).

One male taken on Batbatan Island on June 30, 1918.

Tricentrus robustus Funkh.

Add: *Habitat.*—PANAY, Antique Province, Tibiao, Culasi, and Flores (*McGregor*).

Host.—*Acalypha stipulacea* Klotz.

A series of nine specimens, all females, collected in Panay in 1918 as follows: One taken in the forest at Culasi at 700 meters' elevation on May 18; one from Culasi collected on shoots from a stub of *Acalypha stipulacea* on May 27; three from Culasi, June 1; one from Culasi, June 20; one from Culasi, July 14; one from Tibiao, May 11; one from Flores, June 7.

Tricentrus convergens Walk.

Add: *Habitat.*—LUZON, Manila. PANAY, Antique Province, Culasi. (*McGregor.*)

Host.—*Mallotus moluccanus* (L.) Muell.-Arg.; *Acalypha wilkesiana* Muell.-Arg.

Six specimens collected as follows: Two females and one male taken at Manila, February 14, 1917; one female collected at Manila, February 5, 1917, on *Mallotus moluccanus;* one male from Manila, April 5, 1917, on *Acalypha wilkesiana;* one female from Culasi taken in the forest at an altitude of 700 meters on May 18, 1918.

Tricentrus attenuatus Funkh.

Add: *Habitat.*—PANAY, Antique Province, Culasi (*McGregor*).

Two males from Culasi, one taken in the forest on May 18, 1918, and one at a lower elevation on July 14, 1918.

Tricentrus attenuatus was described from a male, and all of the specimens which I have seen of this species have been of the same sex. This fact makes me suspicious that perhaps we have here the opposite sex of some other species described from female material only. It will be of interest to discover an undoubted pair of this species.

Tricentrus capreolus Walk.

Add: *Habitat.*—LUZON, Laguna Province, Paete, Sarai barrio (*McGregor*).

One female collected on March 19, 1917.

Tricentrus fairmairei Stål. Plate I, fig. 4.

Add: *Habitat.*—LUZON, Rizal Province, Montalban: Laguna Province, Paete. PANAY, Antique Province, Culasi. (*McGregor.*)

Host.—*Solanum verbascifolium* L.; *Eugenia calubcob* C. B. Rob.

Attendant ants.—*Polyrhachis* (*Myrmhopla*) *dives* Smith.

A good series of specimens of this species has been received together with nymphs and attendant ants. Five specimens were collected at Paete on March 18, 1917; eighteen were taken at Montalban, February 22, 1918, on fruit heads of *Solanum verbascifolium* and on young shoots of *Eugenia calubcob;* and one specimen was collected in the forest of Culasi near a 700-meter elevation.

The nymphs (Plate I, fig. 4) were all collected at Montalban on February 22, 1918, on *Eugenia calubcob* and are all in the last instar. Since the immature form of this insect has not been previously recorded, a brief description is given as follows:

Brilliant yellow, marked with black; length, 5 millimeters; width, 3; smooth, shining, not punctate, very sparingly pubescent, head tuberculate above; pronotum with three strong spines, one on median dorsal line and one on each side; mesonotum with one strong median dorsal spine; abdomen with a strong lateral spine on each segment except the last; wing pads reaching the first abdominal spine.

Head much broader than long, bright yellow, smooth, shining, impunctate, only lightly pubescent at margins; base strongly elevated at middle and bearing a strong tubercle on each side of median line; eyes very prominent, produced laterally, jet black; ocelli not visible; sutures distinct; inferior margins of genæ almost transverse; clypeus longer than broad, extending for more than half its length below the inferior margins of the genæ, tip rounded and somewhat pilose.

Thorax distinctly divided into prothorax, mesothorax, and metathorax, not punctate, sparingly pubescent, shining, jet black in front, bright yellow on sides and behind spines; humeral angles very prominent, auriculate; pronotum having three strong spines, one on median dorsal line pointing upward and slightly backward, one on each side above humeral angle projecting upward and outward, an extension of dorsum behind median spine extending to the spine of the mesonotum; mesonotum with strong central spine at posterior margin; metanotum without spine, bright yellow above, jet black at sides; wing pads very well developed, reaching backward as far as the first lateral spine of the abdomen.

Abdomen broad, flattened dorsoventrally, bearing seven distinct segments, of which the first six have strong lateral spines extending directly outward, these spines gradually becoming longer from before backward; entire abdomen shining, impunctate, not pubescent, black above, yellow on sides, apex strongly curved upward; anal tube long, upraised, wider at base than at tip.

Legs and undersurface of body shining luteus.

The form as above described is very apparently in the fifth instar and about ready for the final molt.

Mr. McGregor's field notes on *Tricentrus fairmairei* state that both adults and nymphs are attended by black ants of which he sends specimens. These ants have been determined by Prof. W. M. Wheeler, of Harvard University, as *Polyrhachis* (*Myrmhopla*) *dives* Smith. I am again indebted to Professor Wheeler for his kindness in making these determinations.

Tricentrus acuticornis sp. nov. Plate I, figs. 5 and 6.

Near *Tricentrus convergens* Walker but differing in size and particularly in the formation of the suprahumeral horns. On superficial examination I had placed these specimens with the males of *T. convergens*, which they closely resemble in general appearance; but further study shows them to belong to a distinct species.

Small, dark brown with large white tomentose patches behind each eye, closely punctate, densely pubescent; suprahumeral horns acute, slightly diverging, longer than the distance between their bases, not at all flattened; posterior process straight, extending just beyond internal angles of tegmina; tegmina smoky hyaline; hind trochanters armed with strong spines.

Head a little broader than long, subquadrangular, black, the fine punctures almost entirely hidden by the dense silvery pubescence; base weakly sinuate, rounded, highest above ocelli; eyes very prominent, gray, extending laterad half as far as the humeral angles; ocelli large, pearly, about equidistant from each other and from the eyes and situated above a line drawn through centers of eyes; inferior margins of genæ weakly sinuate, extending slightly downward from eyes to about middle of clypeus; clypeus longer than wide, densely pubescent, extending for somewhat more than half its length below inferior margins of genæ.

Pronotum black, closely punctate, densely pubescent; metopidium perpendicular, broader than high, slightly convex; suprahumeral horns straight, triquerate, acute, longer than the distance between their bases, extending upward, forward, and slightly outward, tips somewhat recurved; humeral angles prominent, auriculate; dorsum almost straight, sloping downward from suprahumeral horns to posterior process; posterior process short, acute, sharply carinate above, tip triquerate, sharp, extending just beyond internal angles of tegmina; median carina percurrent, faint on metopidium, strong on posterior process.

Tegmina much wrinkled, smoky hyaline; base coriaceous, black, punctate and pubescent; tip marked with narrow brown spot at costoapical angle; five apical cells.

Sides of thorax densely white tomentose; undersurface of thorax black; abdomen dark brown; legs ferruginous with bases of femora darker; tarsi ferruginous; claws brown; hind trochanters very prominently armed with strong teeth.

Length from front of head to tips of tegmina, 5.3 millimeters; width between tips of suprahumeral horns, 3.

PANAY, Antique Province, Culasi (*McGregor*), 3 females.

Type, a female, in my collection.

Described from three females from Culasi, one taken May 18, 1918, and two taken May 27, 1918. Type and two paratypes in my collection.

Sipylus dilatatus Walk.

Add: *Habitat.*—LUZON, Manila: Rizal Province, Pasig. PANAY, Antique Province, Culasi. (*McGregor.*)
Hosts.—*Phyllanthus reticulatus* Poir.; *Acalypha stipulacea* Klotz.

Seven specimens collected as follows: One male and one female taken at Manila in April, 1917; one male and two females taken at Pasig, February 17, 1918, on *Phyllanthus reticulatus;* two females taken at Culasi, May 27, 1918, on shoots from a stub of *Acalypha stipulacea.* Mr. McGregor's field notes on this species state that the insects were solitary and were not attended by ants. With the specimens of this species now available for study, it appears that the males average considerably smaller and darker than the females but show the same characteristic broadened pronotum and the nodulate veins on the tegmina.

Gargara varicolor Stål.

Add: *Habitat.*—LUZON, Manila: Rizal Province, Montalban (*McGregor*).
Hosts.—*Acalypha wilkesiana* Muell.-Arg.; *Solanum verbascifolium* L.
Attendant ants.—*Polyrhachis* (*Myrmhopla*) *dives* Smith.

A fine series of this species, of which three specimens were collected at Manila, February 14, 1917; twenty-three at Manila, April 5, 1917, on *Acalypha wilkesiana;* and ten at Montalban, February 22, 1918, on fruit heads of *Solanum verbascifolium* Linn.

This species, according to Mr. McGregor's notes, is gregarious and is attended by black ants of which a number have been received. Professor Wheeler determines these ants as the same species [*Polyrhachis* (*Myrmhopla*) *dives* Smith] as those found with *Tricentrus fairmairei* Stål.

Gargara nitidipennis Funkh.

Add: *Habitat.*—LUZON, Laguna Province, Paete. PANAY, Antique Province, Culasi. (*McGregor.*)

One male and eight females taken at Paete on March 29, 1917, and one female taken at Culasi on May 29, 1918.

This species shows more variation in size than any other species from the Islands, but I can find no specific differences between the large and the small forms.

Gargara nigrofasciata Stål.

Add: *Habitat.*—LUZON, Laguna Province, Paete (*McGregor*).

Three males and one female from Paete. It has previously been recorded[6] that this species also shows considerable variation. The specimens from Paete are larger and darker than the type described by Stål, but agree with specimens from Mindanao collected by Professor Baker.[7]

Gargara tuberculata Funkh.

Add: *Habitat.*—LUZON, Manila (*McGregor*).

One female collected at Manila on April 5, 1918.

Gargara pygmaea Walk.

Add: *Habitat.*—PANAY, Antique Province, Culasi (*McGregor*).

Host.—*Acalypha stipulacea* Klotz.

One female taken at Culasi, May 27, 1918, on shoots from a stub of *Acalypha stipulacea.*

Gargara rugonervosa Funkh.

Add: *Habitat.*—PANAY, Antique Province, Culasi (*McGregor*).

Host.—*Croton leiophyllus* Muell.; *Acalypha stipulacea* Klotz.

One male taken May 18, 1918, on *Croton leiophyllus;* and another male taken May 27, 1918, on *Acalypha stipulacea.* Both specimens are from Culasi.

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[6] Philip. Journ. Sci. § D 10 (1915) 398.

[7] Ibid. 13 (1918) 32.

Gargara pulchripennis Stål.

Add: *Habitat.*—PANAY, Antique Province, Culasi (*McGregor*).
Host.—*Acalypha stipulacea* Klotz.

One male collected May 27, 1918, on shoots from a stub of *Acalypha stipulacea.*

Gargara grisea sp. nov.

Very near *G. tuberculata* and may be only a variety of that species. It may be at once recognized by the very dense gray pubescence which is quite distinctive.

Large, heavy-bodied, light brown, but so covered with dense grayish white pubescence that the body color and the punctation are almost entirely hidden; metopidium convex; posterior process just reaching internal angles of tegmina; tegmina translucent, base and veins densely pubescent with grayish white hairs, veins strongly tuberculate.

Head broader than long, densely tomentose with white pubescence; base regularly sinuate, highest above ocelli; eyes large, prominent, grayish brown; ocelli large but not prominent on account of the dense pubescence, glassy, about equidistant from each other and from the eyes and situated slightly above a line drawn through centers of eyes; inferior margins of genæ almost straight; clypeus longer than wide, densely tomentose with white pubescence, extending for more than half its length below inferior margins of genæ.

Pronotum densely pubescent with grayish white hairs which are thicker near base of head and around humeral angles; metopidium strongly convex; humeral angles large and auriculate; dorsum arcuate; median carina strongly percurrent; posterior process short, heavy, blunt, sharply carinate above, tip just reaching internal angles of tegmina.

Tegmina translucent, not clearly hyaline; base coriaceous and densely pubescent; veins pubescent and strongly tuberculate; tegmina with five apical areas; hind wings with three apical areas.

Sides and undersurface of thorax densely white tomentose; abdomen brown, densely pubescent with white below, segments bordered with white above.

Femora dark brown, smooth; tibiæ ferruginous and spined; tarsi ferruginous; claws brown; hind trochanters unarmed.

Length, 4 millimeters; width between humeral angles, 2.2.

LUZON, Manila (*McGregor*), a pair.

Type, a female.

Described from a pair collected at Manila, the female on February 14, 1917, and the male on April 5, 1917. The male is slightly smaller than the female but shows the same characteristic grayish white pubescence. Type and allotype in my collection.

Cryptaspidia tagalica Stål.

Add: *Habitat.*—PANAY, Antique Province, Culasi (*McGregor*). One female taken June 1, 1918.

Cryptaspidia elevata sp. nov. Plate I, fig. 7.

Recognized by the thick, elevated posterior process and the auriculate humeral angles.

Black, punctate, hairy; no suprahumeral horns; humeral angles projecting as broad rounded lobes; scutellum entirely concealed; posterior process suddenly turned upward at tip; tegmina marked with black.

Head wider than long, black, densely covered with long yellowish hairs which entirely conceal the punctation; base weakly sinuate; eyes large, brown; ocelli prominent, pearly, a little farther from each other than from the eyes and situated slightly above a line passing through centers of eyes; clypeus wider than long, oval, extending only a little below the rounded outline of the inferior margins of the genæ, tip broadly rounded and hairy.

Pronotum black, punctate, thickly covered with long, yellowish hairs; metopidium very convex, rounded, wider than high, slightly flanged at inferior margin; humeral angles produced into broad earlike lobes rounded at tips; suprahumeral horns absent; posterior process short, heavy, much depressed at base, suddenly elevated at apex to form a heavy flattened spine, tip suddenly acute, flattened laterally and having carinæ above, below, and in the center of each side and reaching just beyond the internal angles of tegmina.

Tegmina closely impinging on lateral margins of pronotum; smoky hyaline, base and basal fourth of costal margin black and punctate; faint brown band across center of tegmen below internal angle, most distinct at costal edge.

Undersurface of body black and very hairy. Posterior trochanters unarmed. Legs uniform brown; tibiæ armed with long, thin, spinous hairs, distal ends with black spines.

Length, 7 millimeters; width between tips of humeral angles, 3.8.

LUZON, Benguet Subprovince, Baguio (*Baker*).

Type, a female.

Cryptaspidia longa sp. nov. Plate I, fig. 8.

Very long-bodied, narrow, black, closely and coarsely punctate, sparingly pubescent; posterior process not reaching internal angles of tegmina; tegmina smoky hyaline with very large black veins; scutellum entirely hidden; trochanters unarmed.

Head wider than long, subtriangular, black, weakly punctate, pilose, convex, median suture deeply depressed; base almost straight; eyes large, prominent, black with brown inner borders; ocelli prominent, translucent, yellowish, situated on broad elevations, about equidistant from each other and from the eyes and situated about on a line drawn through centers of eyes; inferior margins of genæ arcuate; clypeus slightly longer than broad, much deflexed, black, punctate, pilose with long golden hairs, tip rounded.

Pronotum entirely black, coarsely punctate, sparingly pilose with long golden hairs; median carina percurrent but weak; humeral angles not prominent, triangular; metopidium strongly convex; dorsum nearly straight; scutellum entirely concealed but present; posterior process short, straight, somewhat flattened, acute, tip sharp and not reaching the internal angles of the tegmina.

Tegmina very long, smoky hyaline, wrinkled; base coriaceous, black, punctate and pubescent; veins very strong, heavy, black, sparingly pilose; tips of tegmina extending well beyond apex of abdomen.

Sides and undersurface of thorax black, densely pilose with long golden hairs; abdomen very long, entirely black, densely pilose below; ovipositor smooth, black, shining, sparingly pubescent; legs ferruginous, tibiæ tinged with darker, tarsi and claws brown, hind trochanters without teeth.

Length, 8.2 millimeters; width, 3.

LUZON, Benguet Subprovince, Baguio (*Baker*).

Type, a female.

ILLUSTRATIONS

PLATE I

FIG. 1. *Centrochares horrificus* Westwood, nymph.
2. *Pyrgonota semperi* Stål, lateral outline.
3. *Pyrgonota semperi* Stål, front view of apex of pronotal horn.
4. *Tricentrus fairmairei* Stål, nymph.
5. *Tricentrus acuticornis* sp. nov., lateral outline.
6. *Tricentrus acuticornis* sp. nov., frontal outline.
7. *Cryptaspidia elevata* sp. nov., lateral outline.
8. *Cryptaspidia longa* sp. nov., lateral outline.

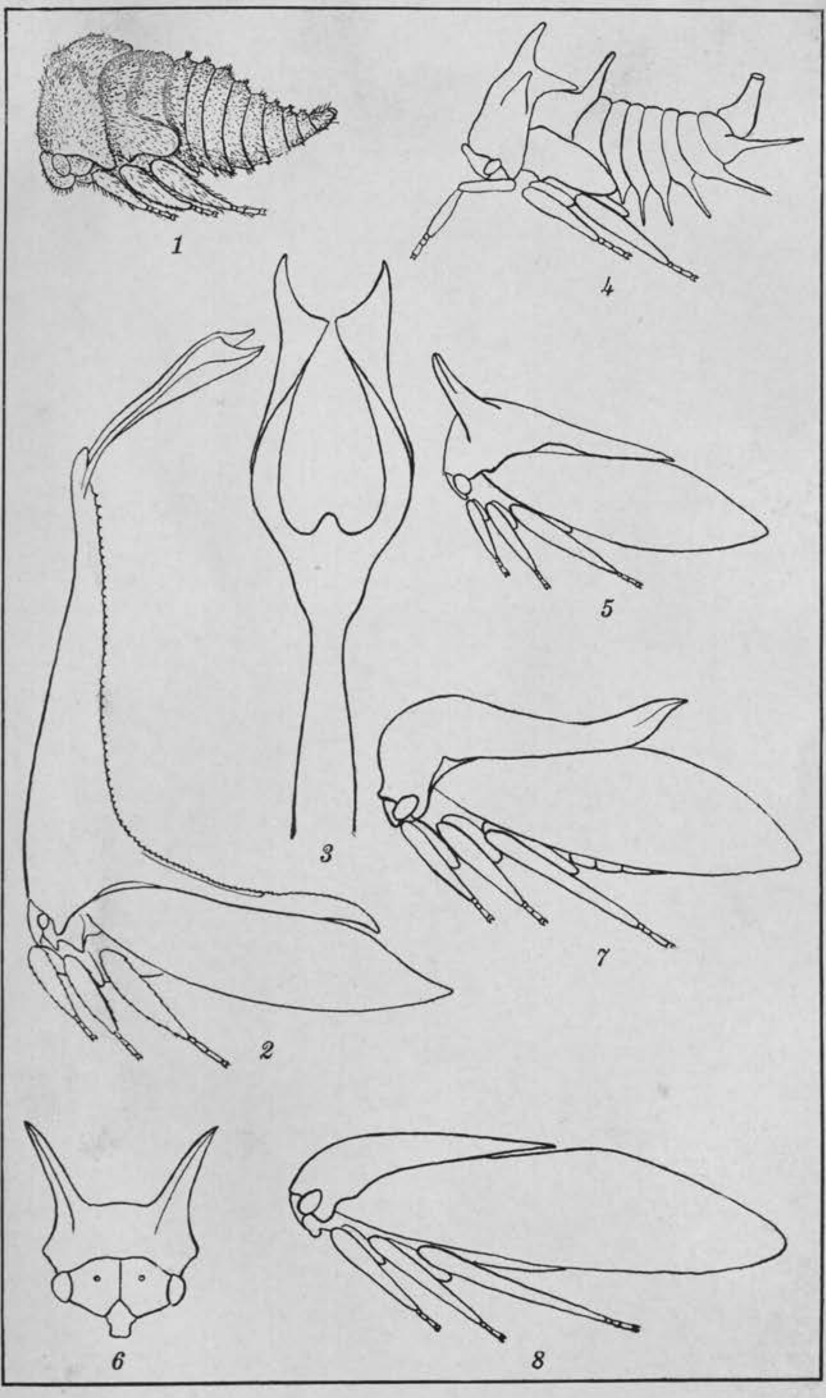

PLATE I. PHILIPPINE MEMBRACIDÆ.

OSTEOLOGICAL AND OTHER NOTES ON THE MONKEY-EATING EAGLE OF THE PHILIPPINES, PITHECOPHAGA JEFFERYI GRANT

By R. W. Shufeldt

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ELEVEN PLATES

Some time during the latter part of March, 1918, the captive specimen of the monkey-eating eagle of the Philippines (*Pithecophaga jefferyi* Grant), of the botanic garden of Manila, died, and the dead bird was immediately sent to the Bureau of Science, Manila. In his letter to me of April 1, 1918, Mr. McGregor stated that from this material he—

> got a good skin—the first! in our collection, although we have a poor mounted specimen. The bones are being cleaned. They will lack the feet, the skull, and the ends of the wings. However, I shall supply a head and a foot from another specimen, so that the thing is nearly complete. The description of this should make a good paper, especially if you can lay hands on bones of the harpy eagle and other related genera.

All this material was received by me in the summer of 1918; and it was in excellent condition. I prepared and photographed the specimens myself. Later, the division of birds of the United States National Museum kindly loaned me certain skeletons, with which I intended to compare the bones of *Pithecophaga jefferyi*. These consisted of an imperfect skull of *Morphnus guianensis* (Daudin), adult (No. 18468); a complete skeleton of an adult *Thallasoaëtus pelagicus* (Pallas), collected by Paul L. Jouy in Korea (No. 18222); an *Aquila chrysaëtos canadensis* (Gmelin), female, adult, complete and disarticulated (No. 18802); a complete, disarticulated skeleton of *Gypaëtus barbatus* (Linnæus) (No. 17834); a complete skeleton, disarticulated, of *Haliæetus leucocephalus* (Linnæus), adult (No. 19278); and, finally, an incomplete skeleton of the harpy eagle, *Thrasaëtos harpyja* (Linnæus), adult (No. 225806). The last-named specimen lacked the skull. This bird was, during life, for several years one of the ornaments of the bird collection of the National Zoölogical Park at Washington. The skull was probably left in the skin. Subsequently I endeavored to obtain a skull of this species from the

Academy of Natural Sciences of Philadelphia, but was unable to do so.

It is very much to be regretted that a skull of the harpy eagle is not at hand for comparison with that part of the skeleton of *Pithecophaga.* Probably there is not a cleaned skull of the harpy eagle in the United States—adult, subadult, or young. This is invariably the case with respect to any bird before a glut takes place in museums and private collections of birds; the skulls are left in the skins!

THE CRANIUM, MANDIBLE, AND ASSOCIATED BONES OF PITHECOPHAGA

It matters but little from what point of view we may regard the cranium of this great eagle, the fact will at once be appreciated that at least two of its characters are so pronounced and so characteristic of the species that to confuse this part of the skeleton with the cranium of any other known eagle would be quite out of the question. In the first place, the lacrymal bones and their accessory outer pieces are of great size, while a still more conspicuous character is to be seen in the size and form of the osseous superior mandible; this is powerfully hooked, with cultrate tomia. It is transversely compressed almost to the last degree, the transverse diameter at the base beneath being slightly less than 2.5 centimeters, while the vertical height at the same point measures nearly 4 centimeters. Measured mesially below, it has a length of about 5.02 centimeters. Either narial aperture is very large, and these openings do not communicate through and through; anteriorly either one merges into the general surface of the side of the beak, while posteriorly greater depth is present, and the surrounding margin is sharp and triangular in outline; the apex of the triangle is posterior and above (Plate I, fig. 1).

Turning to the large lacrymals mentioned above, their form and proportions are well shown in the illustration (Plate I, fig. 2), while the descending limb is portrayed on the same plate. As is the case with so many large raptorial birds, these lacrymal bones, in adult life, do not fuse with the frontal and nasal upon either side nor with the large, subtriangular accessory piece supported at the outer end of each (fig. 2). The descending orbital limb of a lacrymal is constricted superiorly, anteroposteriorly flattened below, while it is broader and concaved in front from above downward. This part of a lacrymal does not come in contact either with the small, thin pars plana within or with the zygoma below.

Passing again to the dorsal aspect of the cranium, it will be observed, in the craniofacial region, that a considerable depression or concavity is present in the median area; posterior to this the frontal region is broad and flat, with the superior orbital margin cultrate. As in most eagles, the broad cranial vault is rounded and smooth, being marked only by the wonderfully fine, rambling, anastomosing lines that in life harbor the vessels of that region. I find these very well marked in the cranium of a white-headed eagle (*Haliæetus leucocephalus*) (Plate II, fig. 1) where, likewise, the depression in the craniofrontal region is pronounced. Throughout the diurnal Raptores, this character varies to some degree for the species. It is fairly well marked in the cranium of *Morphnus guianensis;* and several of the cranial characters thus far described in the cranium in *Pithecophaga* are more or less in agreement with the corresponding ones in this bird (Plate II, fig. 3). This in no way takes size into consideration, for *Morphnus* is not more than half the size of the monkey-eating eagle while, in a way, it does refer to the marked craniofacial depression, the lacrymals, and the general form of the osseous superior mandible. No other parts whatever have been seen or examined by me, and even the remainder of this cranium is very imperfect. When the material was selected for me at the United States National Museum, in addition to those designated by myself, this imperfect cranium of *Morphnus* was included.

In *Gypaëtus barbatus* a lacrymal does not support a free distal piece as in some eagles, while the superior outstanding portion is to a degree elongate and to some extent twisted upon itself. This bird has considerably more eagle in its skull, and in the rest of its skeleton for that matter, than it has vulture. However this may be, it has no special affinity with *Pithecophaga,* in so far as its skeleton would seem to indicate; and it is very much to be doubted that any of the rest of its morphology would point to any such relationship. Nothing would be gained, therefore, by a comparison of the skeletal characters of these two birds, beyond a demonstration of the fact that they possess no near relationship; and this much is evident to any expert avian osteologist at a glance. This in no way applies, however, to such a form as the big eagle of Korea, *Thallasoaëtus pelagicus,* a complete disarticulated skeleton of which (No. 18222, United States National Museum) I have before me. Paul L. Jouy collected it in that country many years ago. In its cranium it exhibits all the aquiline characters of an average eagle, including the accessor pieces on the lacrymals. Upon summing up its cranial characters, however, it is very evident that it is not as nearly related to *Pithecophaga* as is the golden eagle (No. 18802, United States National Museum) (Plate II, fig. 2).

All eagles thus far examined by me possess, upon lateral aspect of the cranium, a deep, rounded, separated crotaphyte fossa; a large, squarish postfrontal process; and a squamosal projection. This does not show very well in fig. 1 of the present memoir, due to faulty lighting of the skull; nor do we, in the same figure, gain any idea of the enormous capacity and depth of the orbit that exists in the cranium of our subject. Indeed, it measures as much as 3 centimeters from the lower edge of the postfrontal process to the edge of the subcircular vacuity in the interorbital septum in *Pithecophaga*. This vacuity is also to be seen in the cranium of the golden eagle, but not in the white-headed species of North America. The anterior wall of the brain case in our subject is markedly concaved on its anterior aspect, and nonperforated beyond the usual foramina for vessels and nerves, all of which latter are comparatively small and individualized. So far as I have examined their crania, this is more or less true of all eagles.

As will be observed in Plate I, fig. 1, the quadratojugal bar in this monkey-eating eagle is quite straight, and of nearly uniform caliber from one end to the other. It is so in all true aquiline species, and in some the maxillojugal suture persists throughout the life of the individual.

A quadrate is a big, stout bone, with a well-developed orbital process, and a broad, smooth surface on its outer aspect. A broad, longitudinal valley lies between the two thoroughly separated articular facets that occur on its lower mandibular portion. It presents two heads for articulation with the skull, and they are separated by a wide, smooth notch. Nearly all parts of this cranium are pneumatic, and to this the quadrate forms no exception.

Either pterygoid bone is small, straight, short, and slender. When duly articulated, it does not come in contact with its fellow of the opposite side. In the golden eagle the outer margin of a pterygoid is very sharp and thin. This aspect in the white-headed eagle is longitudinally grooved, and the posterior extremity of the bone possesses an upturned process for additional articulation with the quadrate.

All true eagles possess a vomer, which is a long, thin plate of bone compressed from side to side, with a finely pointed, free anterior apex; and, further, it is ununited posteriorly with the palatines.

Pithecophaga possesses large, spongy maxillopalatines that fill up a good part of the rhinal chamber, being carried far to the front above the prepalatines, where they appear to merge to a slight degree. They are separated for their entire length in *Aquila,* but extensively fuse in *Haliæetus leucocephalus,* where they form a nearly solid roof in the mouth in connection with prepalatines and maxillaries.

Pithecophaga has a very solid bony nasal septum, as has the white-headed eagle; while in the golden eagle a good-sized vacuity may occur at the posterior superior angle.

The hinder part of a palatine in any true eagle has the postero-external angle rounded off, the bone in this locality being rather broad, with its inner margin produced and turned down, and its outer one to some degree thickened. In this part of their extent the palatines are in contact with each other, clasping the vomer between them anteriorly and the sphenoidal rostrum above.

The basipterygoidal processes are entirely absent in the skulls of all the eagles at hand at this writing, save in the case of the golden eagles, where they are represented by small triangular prickles, flattened from above downward. A lip of bone usually underlaps the entrances to the carotid arteries.

Pithecophaga—and other species of eagles depart but little from it—presents a triangular area for the basitemporal space of the cranium, with a marked depression just anterior to the hemispherical occipital condyle. The foramen magnum is large and nearly circular in outline. A superoccipital prominence is fairly well developed in all these eagles, including the Korean species.

Although the "occipital area" is well defined, the ridge that exists to mark its limitations is not much raised. This is also true of the "crotaphyte fossæ," which are extremely shallow, subcircular in outline, and widely separated posteriorly. At the side of the cranium the crotaphyte fossa extends over onto the external surface of the postfrontal apophysis.

The cranial capacity is only of moderate proportions, when taken in conection with the balance of that part of the skull; and this is especially true of the cranium of *Pithecophaga.*

Laterally, the osseous aural apertures are much exposed; in life, however, the soft structures of the internal ear are more or less protected by the conformation of the quadrate when that element, upon either side, is placed in articulation.

There are some twelve to fifteen sclerotal plates to the circlet in either eyeball; the smaller ones are situated anteriorly and the larger ones behind (Plate III, fig. 9). Each platelet is an irregular quadrilateral in outline, the whole arrangement being fitted to the requirements of the form of the external moiety of the globe, assisting very materially in protecting it from certain injuries, and maintaining the sphericity of the organ. Additional strength is afforded through the generous overlapping of the plates.

We find the characters presented on the part of the mandible among the eagles pretty much the same, and it is V-shaped in all of the species at hand. In the long-faced species the V is more elongate, and the angle formed by the rami more acute. The bone is more or less pneumatic, which is also true of the cranium as a whole. In *Pithecophaga* a side of the mandible has a length of 9.7 centimeters, and the symphysis 2.5 centimeters, the latter being concave transversely above and correspondingly convex on its ventral aspect. All the elements are very solidly fused together, with the superior and inferior borders rounded. There are no perforating vacuities anywhere, the entire bone being very strong and smooth. A low coracoid process is present on either side, and from either of them the superior border slopes rather abruptly downward to the articular enlargement of the same side (Plate I, fig. 1; Plate III, fig. 4). Posteriorly, an articular extremity is considerably compressed from above downward, being truncate posteriorly. Its mesial, inturned process is somewhat elongate and well developed, with the usual pneumatic foramina near its apex superiorly. These processes are directed upward and inward, the apex in either case being blunt. Each presents two surfaces ventrally, and these are smooth. One surface is continuous with that of the jaw, the other pertaining to the underside of the inturned process.

Superiorly either one of these articular ends is concaved centrally, and that surface does not come in contact with the quadrate of the same side in articulation. Upon either side of this concavity, however, internally and externally situated, there is to be noted a conspicuous articular facet for articulation with the corresponding ones on the quadrate of the same side.

In many publications, here and abroad, I have described the skeletons of various species of eagles, falcons, hawks, and their near congeners, both fossil and existing forms, and it may be said that we meet with few marked differences in any of them with respect to the characters presented on the part of the hyoidean arches, or skeleton of the lingual apparatus (Plate III, fig. 10).

The anterior soft part of the glossohyal is long and narrow, being covered for its anterior two-thirds with the usual horny sheath. Posterior to this, the glossohyal is narrow and bifurcated, articulating, as usual, with the basihyal posteriorly. This part is likewise thinly overlain with a horny sheath. All this part is very feebly developed, extremely elongate, and narrow.

Triangular in outline, the basihyal supports posteriorly an elongate urohyal, which is of small and nearly uniform caliber; it is tipped off with a very small bit of cartilage behind. This urohyal is perpendicular to the transverse line of the base of the basihyal, and in the right angle upon either side of the former articulates the head of a hypobranchial. Each hypobranchial is long and curved upward for its entire length. Both the anterior and the distal ends are somewhat enlarged, the posterior enlargements being continued in cartilage for a few millimeters, when, upon either side, its place is taken by a ceratobranchial. Either one of these is about 1.5 centimeters long, slender, and to some extent curved in line with the upcurved hypobranchial of the same side. Each ceratobranchial terminates behind in a fine, needle-pointed, cartilaginous tip.

Our white-headed eagle (*Haliæetus leucocephalus*) possesses a hyoid very similar to this; but the angle made by the urohyal and the basihyal is an obtuse one instead of a right angle, as it is in *Pithecophoga*, and the cartilaginous part of the glossohyal is extremely short, while the broad, osseous part has the form of a capital letter H, with the sides converging toward each other from behind forward.

Eagles, in so far as I have examined them, possess a very simple form of larynx and trachea. The former presents the usual osseous elements, but they form no special articulations with each other, the contour of the structure being sustained in their membrane, with the aforesaid elements simply maintained in their several positions by it, and nowhere in contact with each other. All the tracheal rings—and they are very numerous—appear to be, to some extent, performed in cartilage (Plate III, figs. 6, 10). Each is of the usual ornithic type, the broader ones being above and below. There are upward of seventy of them, the lower end of the tube not having more than half the caliber of the upper, where it makes a simple union with the larynx. Distally, the bronchial branches are small, and but half closed in, the mesial aspect of either being a thin, simple membrane stretched across. There is a single pessalus present.

THE SKELETON OF THE TRUNK

The vertebral column.—All the skeletons of eagles that I have examined possess fourteen vertebræ in the cervical region of the spine, between the cranium and the first true dorsal vertebra. Each of the last two cervicals—the thirteen and the fourteenth —supports a free pair of ribs. On the thirteenth the pair is rudimentary, to the extent that the body of the bone on either side is lacking to some considerable degree, while the articulation is perfect for the head and angle. With respect to the pair of ribs on the fourteenth cervical vertebra, it has a length of some 5 centimeters, terminating in a pointed, free extremity well above the sternum. As this is the case with respect to these last two vertebræ in *Pithecophaga, Thrasaëtos harpyja, Aquila,* and our white-headed eagle, it is probably what we will find in the skeleton of any true aquiline species, irrespective of the part of the world it inhabits. As a matter of fact, the vertebral column of this monkey-eating eagle of the Philippines is, character for character, almost the counterpart of that series of bones in the harpy eagle, and departs but very little from what we find in other species.

In our present subject the atlas lacks both neural and hæmal spines, while the articular cup for the occipital condyle is notched above. Laterally, there may be a notch or a foramen for the passage of the vertebral artery upon either side. Its neural arch is rather broad, and the facet for the centrum of the axis is quadrilateral in outline, the width being twice that of the vertical height. At the middle point below, it is pierced longitudinally by a minute foramen; a broad notch being found at the same place in the atlas of the white-headed eagle. In this species, too, similar notches allow, in life, the passage of the vertebral arteries to the cranial cavity. Similar ones, though larger, are to be seen in the axis of *Pithecophaga,* in which vertebra are developed a stumpy hæmal and a neural spine, as well as a more or less insignificant odontoid process.

The neural canal throughout the cervical series of vertebræ is cylindrical in form and quite uniform in caliber. From the third to the twelfth vertebra, inclusive, the lateral foramina for the vertebral arteries are, in all instances, entire—that is, with respect to their osseous walls; on the other hand, the carotid canal is an open passage for the arteries of that name in the fifth to the ninth cervical vertebra, inclusive (Plate III, figs. 3, 5, 7, and 8).

All of these cervical vertebræ are very large and strong—indeed, quite massive in character. When present, the neural spine is situated just within the posterior margin of the bone; it is directed backward and upward in the third vertebra; is vertical and peglike in the next following one, with broader and triangular base in the next three (fifth to seventh inclusive), wherein it moves forward to the middle of the neural arch, the angle being situated anteriorly, and either side being directed backward and outward.

In the third cervical the prezygapophyses and postzygapophyses are joined by a plate of bone, in which appears, on either side, a small elliptical foramen; this foramen in the next following vertebra becomes an extensive subelliptical notch, being reduced to a minute spine on either side in the fifth vertebra.

Returning to the matter of the neural spines, we find that the broad, triangular form they assume—described in a previous paragraph—persists in the eighth to the twelfth vertebra, inclusive. Here they are more massive and occupy an extreme posterior position on the several remaining vertebræ of this series. On the twelfth the spine begins to assume the form of the neural spine as we find it in the leading dorsals, while in the thirteenth and the fourteenth not only are the neural spines in agreement with those processes in the thoracic vertebræ, but they present almost all the other characters of that series. In the midcervical series, the pleurapophyses are short and stumpy.

The rather massive prezygapophysial processes in the fifth cervical face directly upward; in the sixth they look inward and backward, and they maintain this position to include the ninth. In the rest of the series they face inward again. The "carotid canal" is present and open in the fourth to the eighth cervical, inclusive, being most nearly closed in the last one named.

Coming to the dorsal vertebræ (Plate IV), we find them very closely interlocked in articulation, with long, spinelike metapophyses on the last four of the five which occur in this section of the spinal column. The hæmal spines are stumpy and short, being entirely absent on the last two dorsals. The neural canal is cylindrical in form; the facets for each pair of ribs are entire and are situated well back from the anterior limitation of the centrum on any particular vertebra; that is to say, there are no demifacets (Plate VI).

There are no epipleural appendages on either the last pair of the cervical ribs or the last pair of the pelvic ones (Plate IV); and, while of no great size on the first pair of dorsal ribs and the leading pair of pelvic ribs, they are conspicuously long and massive on the ribs of all pairs constituting the midseries. Any of these, in articulation, overlaps the body of the next rib behind; and all of these processes, at least in adult life, are very extensively and firmly coössified to the rib to which in any case they belong. With respect to direction, they all point upward and backward.

In the harpy eagle the basic portion of any one of these epipleural appendages is notably extensive, and occupies, in the case of the second pair to include the fifth, a large part of the posterior border of the rib—fully a third at least. There is a smaller pair of these apophyses on the last pair of pelvic ribs (Plate V).

All the ribs in *Pithecophaga,* save the cervical ones, articulate with the sternum by means of costal, or sternal, ribs; and there are no floating ones on the last pair as there are in the case of the harpy eagle (fig. 17). In our subject these sternal ribs increase in due proportion, in size and length, as we proceed from the first to the last pair; they are more or less massive, in keeping with the rest of the skeleton of this ponderous bird, and the last two pairs exhibit more or less upward curvature (Plate IV).

Our white-headed eagle has the last pair of pelvic ribs more or less feebly developed. The thoracic pair, upon one side or the other, may be more or less aborted with respect to its length and not descend to meet the usually well-developed corresponding pair of sternal ribs in this bird.

The pelvis and the caudal vertebræ.—When we come to examine and compare the pelves of various species of eagles from different parts of the world, we are struck by the marked similarity of form and of characters among them. This applies with special significance to the pelvis as we find it in our present subject and in the harpy eagle. Here the different characters are of the most trivial description possible—so much so, indeed, that a detailed account of the pelvis of an adult *Pithecophaga jefferyi* would answer admirably for the same bone of the skeleton in the harpy. Upon comparing Plates IV and V of the present memoir, it would appear that the disposition of the hinder part of the pubic style was very different in the two birds; but this is by no means the case, for in the harpy those elements are held in their normal position, as in life, by a ligament stretching between their distal ends; while in *Pithecophaga,* when this ligament has been cut, it allows the pubic styles to spring away from each other and hang down as shown on Plate IV. Moreover, the point of view from which I photographed those two trunk skeletons was not quite the same, and this causes the reproduction of the rest of the bone to present slight differences, which do not really exist.

Viewed from above, it is to be noted that the ilia project considerably beyond the sacral crest; and on the upper surface of their anterior border there is a raised emargination which is produced backward and finally runs out as a bounding line to the postacetabular area of the superior surface of the sacrum upon either side. As the ilia pass the "sacral crest," their margins thoroughly coössify with it and in the same plane anteriorly—that is, up to the point where these bones begin to diverge and are raised above the general surface on this dorsal aspect of the bone. At the angle where this divergence commences, the sacrum and the ilia are completely fused, and every semblance of posterior openings of the "ilioneural canals" is completely obliterated. So, too, with the rather abruptly downward-sloping "postacetabular area;" here, likewise, every semblance of sutural traces—the intersacroiliac ones—has been absorbed; while the intervertebral foramina, so conspicuous in this area in the pelves of some birds, are reduced to mere little pits in the general surface of the bone (Plate VI).

Seen upon lateral aspect (Plate IV), the anterior two-thirds of bone—or all that part anterior to and above the acetabulum and antitrochanter—is supplied by the ilium of that side. Its surface is generally concaved and faces upward and outward. Anteriorly, its outer border is emarginated, and below this may be seen the forepart of the pelvic sacrum, the continuation of which, posteriorly, may also be observed through the large, circular acetabulum and immense ischiadic foramen; the former is entirely lacking in any osseous base, while the latter occupies fully one-half of the lateral area posterior to the rather large, subtriangular antitrochanter and elliptical obturator foramen. Posterior to this great ischiadic foramen, the lateral surface of the ischium is triangular in outline, concave above, convex below, and smooth throughout. The rounded posterior ischiac border is nearly straight and presents no semblance of any indent that might suggest the presence of an "ilioischiadic."

The pubic style closes the obturator foramen; and, after passing it along the lower margin of the ischium, it becomes much attenuated and terminates as a fine point in a line below the middle of the ischiadic foramen above it. A small interval is then present, when the bone begins again in a fine point, to increase gradually in size as it passes below the inferior ischiac border, to be produced posteriorly in a much thickened condition in the direction of its fellow of the opposite side.

Ventrally, the pelvis of this eagle presents many interesting features. As well as I am able to judge from the pelvis of an adult bird of this species, the sacrum would seem to contain fifteen vertebræ, or the same number as we find within the grasp of the iliac bones of the harpy's pelvis. The leading seven possess very large centra, and they have their lateral processes extending upward and outward, to coössify with the ventral surfaces of the ilia. Posterior to this arrangement, we arrive at the very deep pelvic basin, where the three vertebræ opposite the cotyloid rings fail to throw out lateral processes. These are followed by three others that have the lateral processes for their external moieties fused into a common plate of bone upon either side, which fuses outwardly with the inner surface of the pelvic wall. A row of three elliptical foramina is left upon either side of the centra here, and osseous trabeculæ are thrown up into the deep space above. Finally, the two terminal sacral vertebræ occupy a much lower plane than the preceding—that is, their transverse processes do—and these are thrown directly outward, to fuse distally with the inner wall of the ischium upon either side. Below them the surface—and it is an extensive one—on either hand is smooth, being furnished entirely by an ischium.

The conformation I have attempted to describe here gives rise to four fairly well-defined cavities, each imperfectly walled in by the surrounding parts of the pelvis as a whole. Through these cavities, mesially, passes the big, coösified pelvic "sacrum." The first cavity occupies the anterior half of the pelvis backward to a point where the vertebræ cease to send their lateral processes directly outward to the iliac walls upon either hand. Then follows the well-marked, deep cavity opposite the acetabulæ; posterior to this we define cavity number three, which lies between the big ischiadic foramina; and, finally, ventrad to the last two, there is the general concavity of the pelvic basin, having cavities two and three above it, and its lateral walls formed by the ischium, descending deeply upon either side.

The skeleton of the tail of this eagle is composed of eight free vertebræ, plus a large, quadrilateral pygostyle. The first three vertebræ are pneumatic, while the rest of this caudal series does not enjoy this condition. Passing to the harpy eagle, we find that the tail skeleton contains but seven free vertebræ and a pygostyle; the latter is similar to that of the monkey-eating species, but here the leading four vertebræ are pneumatic—the rest are nonpneumatic (Plate III, fig. 1, and Plate V). These vertebræ, including the pygostyle, are massive in structure, and present the usual ornithic characters of this part of the vertebral skeleton in the aquiline types.

Pithecophaga possesses a very large quadrilateral pygostyle, the lower portion of which seems to be a coössified terminal caudal vertebra, though now an inherent part of the bone and included in giving to it its peculiar shape. Superiorly and anteriorly the pygostyle possesses sharp edges, while the posterior one is thickened and rounded. Above its articulation in front, there is a small opening for the terminal of the spinal cord to enter, and below this, a double-faced articulation for the last free caudal vertebra. Just posterior to this the pygostyle is perforated from side to side by a smooth, subcircular foramen of some size (Plate III, fig. 2). The lower half, posteriorly, has the form of an isosceles triangle, with the apex above. Its sides are rounded, and its base is much thickened. Interiorly it is excavated, and the above-described foramen passes through the excavation, while the floor of the excavation exhibits a larger foraminal opening of an elliptical outline, with the major axis in the anteroposterior line.

In the harpy eagle a stumpy apophysis projects from the superoposterior angle of the pygostyle, while the foraminal openings are generally smaller. Throughout the falconine types of the world the pygostyle, while it may vary somewhat in form, possesses the same general characters, is always conspicuously large, and is commonly of a quadrilateral form.

Bones of the shoulder girdle, or pectoral arch.—Taking into consideration the marvelous power of flight possessed by this big eagle, we need experience no surprise at finding the bones composing this distinctive arch as in all birds of great strength, massive in structure (Plate IV). This is preëminently true, and probably no existing bird of its size possesses bigger and stronger bones in its shoulder girdle than an average eagle; to this statement our aquiline giant of the Philippines forms no exception. As is the case with all the bones of the trunk skeleton, they are highly pneumatic in character, and consequently very light in weight for their size.

The os furculum, or fourchette, has the form of a very wide-spreading capital U; the lower part of the arch is not especially strong, while it rapidly increases in size from below upward, to terminate in immense, free clavicular extremities. Either of these is much compressed from side to side, with its great superior end accurately molded, externally, to the mesial head of the scapula of the same side. When duly articulated, its apex barely comes in contact with the anteromesial angle of the head of the scapula of the same side.

The clavicular limbs of the furculum are greatly compressed from side to side, and the edges thus formed are sharp, especially the mesial ones. There is but small evidence of a hypocleidium, and the entire bone is powerfully curved backward and upward. Its pneumatic foramina are principally situated in the concavities of the upper clavicular extremities, upon their moderately shallow outer concavities, on that part of the bone, upon either side, which goes to complete the foraminal passage among the heads of the three bones of this girdle.

The os furculum in the skeleton of our subject agrees very well with the corresponding bone in the harpy eagle; though in the latter species the free clavicular ends are more extensively rounded off than they are in the case of the Philippine bird. Our white-headed eagle possesses a more delicately fashioned furculum, while in such a form as *Thallasoaëtus pelagicus,* of Korea, the clavicular free ends are enormously developed; but, owing to the high degree of pneumaticity, the bone, as a whole, is extremely light in weight. Doubtless other eagles present still other differences, not only in the furculum, but also in the remaining bones of the girdle.

When articulated as in life, the coracoids in *Pithecophaga* do not meet in the median line, being separated by an interval of several millimeters. Either bone is very massive in form; but is light in weight, owing to the high degree of pneumaticity it enjoys. All of its parts are conspicuously developed, the broad scapular process being perforated by a foramen piercing it from before backward. There may be pneumatic foramina of some size on the mesial aspect of the big head of the bone and still others on its outer aspect. A sternal extremity is considerably expanded, the bone in articulation extending beyond the sternum laterally. Here it is much compressed from before backward, and thickened at its mesial angle.

The harpy eagle possesses coracoids very similar to those of *Pithecophaga*, while in the American white-headed species the head of the coracoid is much compressed from side to side.

In agreement with the other bones of its pectoral arch, *Pithecophaga* possesses a scapula of great size and unusual strength. As in the case of the coracoid and the furculum, it is highly pneumatic, the foramina for the admission of air into its interior being found on the ventral aspect close to the head of the bone. The head is broad from side to side and somewhat compressed from above downward; at its outer angle there is an elliptical articular surface that constitutes about one-third of the glenoid cavity, while at the mesial angle a big quadrilateral process projects forward for the attachment of the coracoscapular ligament. The neck of the bone is broad and thick; the borders are rounded off. This part constitutes about one-third of the blade; posterior to it we have the curved scimitarlike blade of the bone. This is carried backward to a blunt point, the outer border being rounded, and the mesial one having a thickened edge; the latter commences abruptly near the middle point of the bone as a whole. From head to apex this scapula presents a uniform and gentle curvature in the plane of the bone's blade, the concavity of the curve being along the outer border.

The harpy eagle has the distal moiety of a scapula very broad, with the outer margin sharp, but the inner one rimmed pretty much as we find it in the monkey-eating species. In the golden eagle the terminal part of the blade is distinctly truncated, and the entire bone is much compressed from above downward. This is also true of the scapula in our white-headed bird; here the blade is extremely narrow and is drawn out posteriorly to a truncated apex. In this species it does not seem to be especially pneumatic. The Korean eagle has a scapula resembling that bone in the golden eagle.

These birds—*Pithecophaga* forms no exception to the rule—possess a big sternum of extraordinary capacity. Ventrally it is one deep basin from side to side as well as lengthwise. Down the middle line there is a row of scattered foraminal openings to admit air during the life of the individual. Its xiphoidal border is at right angles to the long axis of the bone and presents but a shallow concavity for its middle third. Well within this border, upon either hand, there is an elliptical foramen of no great size. Seven facets occur upon each costal border, with a great many pneumatic foraminal openings among them. Their interarticular cavities are very shallow. On the outer aspect of the body of this sternum, at the anterosuperior angle and including the distance occupied by the first four hæmapophysial articular facets, there is a marked concavity which is the continuation of the costal groove of the same side. Its lower boundary is curved, with the convexity toward the keel (Plate IV). The keel is not deep by any means and is continued only two-thirds the length of the body, its lower border being uniformly convex. Anteriorly, the carinal angle is rounded off, the concave, anterior border above it being sharp for its lower half and flat for its upper, terminating superiorly in a stumpy manubrium, which is truncated anteriorly, leaving, as it were, a small, triangular surface, with the angle below in the middle line. The deep coracoidal grooves are remarkably well defined in front, in the middle line, at which point they decussate to some extent.

The external surface of the sternal body, upon either side of the carina, is smooth, and the line of the pectoral muscle is but faintly defined. Occasionally we find in the body of the sternum of this and other eagles one or two small, sporadic foraminal openings, just as though a bird shot had made a perforation and the wound subsequently healed. I find a rather large, nearly circular one of these in the sternum of the harpy eagle, it being situated on the right side of the body of the bone, near its middle. In this species the sternum is somewhat smaller than the one just described; but, ventrally, it presents the same profound concavity, with fewer evidences of pneumaticity, however. The xiphoidal elliptical foramina, one upon either side, are very much larger; and this extremity of the bone has an increased width due to the lateral extension of the xiphoidal portion, which is well seen upon lateral view (Plate V). There is the same number of articular facets upon either costal border as we described for *Pithecophaga jefferyi*—indeed, all eagles seem to have the same number. The Korean eagle lacks any foraminal openings in the xiphoidal end of the bone, and the sharp border there is entirely lacking in notches, being wholly at right angles to the carina, which fails to run out to it by at least 2 centimeters. Within the thoracic cavity of the body of the bone foraminal perforations occur not only down the middle line of the bone to a point opposite the last pair of facets on the costal borders, but likewise in a great area in front and along both sides to a similar point. The coracoidal grooves decussate in this eagle, as they do in the white-headed species, and they are invariably of some considerable depth. In the latter bird there is also an absence of the xiphoidal foramina, and that border presents a squarish prolongation of no great size in the middle line; it possesses all the other aquiline characters of this bone.

In the bearded vulture, of Europe, the body of the sternum is square in outline, and not a parallelogram as in eagles; its coracoidal grooves do not decussate, and it has but six pairs of costal ribs. In fact, the bone is that of a big vulture, and in no way suggests that of an aquiline species of any sort.

The pectoral limb.—Plates VII and VIII. It has long been a well-known fact that all big raptorial birds possess limbs of great size, power, and proportions. This is what we would usually look for when we come to consider their habits and the character of their prey. It also explains the fact that most of the bones of their limbs enjoy a very perfect state of pneumaticity; the skeleton of the foot, however, often forms an exception to this condition. Possibly, in some of our eagles, even the foot bones may be pneumatic; they appear to be so in some degree in our white-headed species, but surely not in the golden eagle. True vultures, almost without exception, possess a skeleton presenting a lightness and an extremely perfect pneumaticity unequaled by any other family of birds. *Gypaëtus* forms a partial exception to this rule, in so far as the skeleton of its feet is concerned; but this bearded species approaches the eagles, while our American vultures are birds that practice long-sustained and steady flight, and do not capture their prey—hence a more perfect aëration has evolved in them.

In the different species of eagles, in so far as I have examined them, the humerus varies but little in form or in general characters. It is invariably a large and thoroughly pneumatic bone, and to this statement *Pithecophaga* presents no exception. It has a length of about 20 centimeters; and, taken as a whole, its shaft presents the "sigmoid curve" in a nearly perfect degree. Rather less than its middle third is very smooth and quite cylindrical in form. Its radial crest is short and triangular in outline, while the ulnar tuberosity is very conspicuously developed and arches over—to some considerable extent proximally—the deep pneumatic fossa, in which may be seen the pneumatic foramina of very large size, but generally few in number. There is also a row of these foramina along the base of the smooth, elliptical head of the bone on the anconal side; they are of no great size in this locality. A very distinct elongate elliptical area—raised above the general surface—with its major axis parallel to the bone's shaft, may be seen at the distal base of the radial crest on the palmar aspect of the expanded proximal end of this humerus; it denotes the place of insertion, in life, of the pectoralis muscle, and is found in the same location in all true eagles.

All of the ornithic characters seen in the avian humerus, in so far as falconine species go, are to be found at the distal end of this bone of our present subject, and each and all of them are unusually prominent. This applies especially to the two articular tubercles, the trachial fossa, and the tendinal grooves on the anconal aspect. In the aforesaid fossa a few, small, scattered, pneumatic foramina may be observed, especially just beyond the radial and ulnar tubercles.

The radial crest of the left humerus of this individual exhibits the results of some previous disease, and it has manifested itself in the form of quite an extensive exostosis. The ulnar crest is carried down onto the shaft for a distance of about a centimeter as a sharp and distinct border; while at its middle we note a small foraminal perforation, with a groove leading into or out of it, on the palmar surface of the proximal, expanded extremity of this bone.

This foraminal perforation is absent in the radial crest of the humerus of the harpy eagle, and the crest itself is of a triangular outline (Plate VII, fig. 2); while otherwise, in all other matters, the two bones are notably similar in these two eagles. However, in the harpy it may be noted that the caliber of the shaft is greater and presents less sigmoidal curvature.

In the Korean eagle (*Thallasoaëtus pelagicus*) the humerus is fully 1.5 centimeters longer than it is in *Pithecophaga jefferyi;* it is also straighter and somewhat slenderer. Its large, triangular, radial crest extends farther down the shaft, while in all other respects the two bones are very similar. Curiously enough —the above fact notwithstanding—the skull of the Korean bird is neither as large nor as massive as is the skull of the eagle of the Philippines. This difference is possibly due to a longer wing in the former species; but the material is not at hand at this writing either to prove or to refute any such statement.

In September, 1918, I published an account of *Pithecophaga jefferyi,* illustrated by natural-sized figures of its head and foot.[1] In that article I made the statement that the species was the largest of all existing raptorial birds. Possibly this may be so; while, upon the other hand, the big eagle of the Orient (*Thalla-*

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[1] Am. Forestry 24 (1918) 555–557, 2 figs.

soaëtus pelagicus), found in Kamchatka and Japan as well as in Korea, may be a bigger bird in some respects. Sharpe included the Old World vultures in the true raptorial group. In the genera *Vultur* and *Serpentarius* there are some big species the comparative weights and proportions of which have never been taken for a series of living specimens or compared with the corresponding data on *Pithecophaga jefferyi.*

I have never compared the wedge-tailed eagle, *Uroaëtus audax* Lath., of Australia and Tasmania, with our present subject; but I am inclined to believe that it is not so large a bird.

The radial crest of the humerus of the white-headed eagle of the United States is also triangular in outline; while in *Aquila chrysaëtos canadensis* this feature of the bone under consideration is not so lofty and, while triangular in general outline, it extends very much farther down the shaft of the bone. Here, too, the osseous emargination of the pneumatic fossa is broader and more extensive, thus closing in upon the true cavity, though in no other way diminishing its capacity.

The bearded vulture of Europe has a humerus fully one-third larger than that bone in *Pithecophaga,* and its characters are very similar, the most striking departure being the shallow pneumatic fossa in the former species, with all of its foramina merged into one subcircular foramen.

In the antibrachium of *Pithecophaga* both the ulna and the radius exhibit some degree of curvature between proximal and distal extremities. Air gains access to their interiors through minute foramina at the proximal and the distal end of each; at the latter situation they articulate in the usual manner with the radiale and the ulnare of the carpus, bones that here present the avian characters usually seen among the eagles. The radius has an extreme length of some 20.5 centimeters, and the ulna is about 2 centimeters longer than this. The latter bone has a double row of osseous papillæ down its cylindrical shaft; these, as in other birds, are for the attachment of the quill butts of the secondary feathers of the wing. There are ten in each row, and all, to the last pair at either end, are opposite each other. The anterior third of the radius is subcylindrical in form, while the remainder of the shaft is trihedral on section. Its "radial tuberosity" is concaved in the center, with the inner margin sharp. Our harpy eagle skeleton lacks the bones of the forearm and manus.

Thallasoaëtus pelagicus has the radius and the ulna much longer than the monkey-eating eagle, and each is markedly slenderer. We are also to notice that the papillæ on the shaft of the latter are closer together. Ten pairs of them appear to be present, and the ulna in this bird has an extreme length of 24.3 centimeters.

America's golden eagle departs from others examined, in that the humerus and the femur are the only pneumatic bones of the pelvic and pectoral limbs.

Unfortunately, I have not at hand the skeleton of manus either in the case of the harpy or of the species here being osteologically considered; so that a description of these parts will have to be undertaken by someone else, when such material falls into the hands of science. Very likely, in other published papers of mine, descriptions of these parts of the skeleton in other species of eagles will be found, either of fossil or existing species.

The pelvic limb.—Plate VII, fig. 1; and Plates IX, X, and XI. *Pithecophaga jefferyi* possesses a big femur, which is permeated by air in all of its parts. There is an extensive group of pneumatic foramina in the deep popliteal concavity, and another large opening on the proximal end of the bone anteriorly, at the termination of the trochanter major; it is bounded internally by the linea aspéra. Caput femoris is sessile, with an extensive pit for the ligamentum teres. The summit is smooth and convex from before backward, and concave from head to the trochanter, which latter rises above the summit of the bone. It is very broad and rough on its external surface. Passing to the shaft, we find that to be very stout and uniformly arched, the convexity being in front. For its middle third it is subcylindrical in form and very slightly roughened throughout.

Distally the condyles of this femur are enormous with very prominent articular surfaces. The side of the inner condyle is, for the most part, flat and smooth, while the outer one is slightly roughened and presents a conspicuous tuberosity. As usual, this condyle is vertically divided posteriorly, in that it may articulate with the head of the fibula of the leg. This femur has an extreme length of about 13.2 centimeters, or 2 millimeters more than the length of the femur of a harpy eagle; but the little that the harpy lacks in length in this bone it amply makes up in stoutness; and, apart from this general stoutness, there is no specific difference worthy of notice or description.

The femur of the golden eagle is of about the same length as the two just noticed; but it is a far slenderer bone, with the elliptical pneumatic foramen at its proximal end very conspicuous, and the muscular lines on the shaft are likewise so. The popliteal cavity is shallow in the femur in this species, as it is in some other eagles. *Haliæetus leucocephalus* also has a slenderer femur, while *Thallasoaëtus pelagicus* has one of moderate proportions—that is, not as long or as stout as in *Pithecophaga,* and the shaft is slightly more curved. In the femur of this species the noteworthy characters consist in the great prominence of the tubercle on the outer condyle and the unusual depth of the pit on the caput femoris for the ligamentum teres.

Air does not enter so extensively into the bones of the leg in *Pithecophaga* as it does in the case of the femur. Still, they are to some considerable degree pneumatic; for, upon ordinary maceration, the bones largely whiten, though not nearly as much as does the femur, while in no part do they turn fatty yellow, as happens to the metatarsus and toe bones after similar treatment.

The tibiotarsus in *Pithecophaga* measures some 20.4 centimeters in length, and the fibula measures 15.8 centimeters (compare Plate VII, fig. 1, and Plate IX, figs. 2 and 3). The first-named bone is nearly straight from end to end, being but very slightly arched to the front. For its distal third it is markedly flattened in the anteroposterior direction—less so above, where it is flat for its anterior surface and sides, the shaft being here trihedral on section. Distally the condyles are very much suppressed posteriorly and correspondingly pronounced in front, where the valley between them is deep. Above them, to the inner sides, the tendinal groove is of great depth; it is very distinctly defined as to its boundaries, and the oblique "tendinal bridge" is strong and similarly characterized.

Proximally the raised ridge for articulation with the fibula has a length of 3.5 centimeters and lies wholly within the upper third of the shaft, which here is very flat and smooth. Above this we note the low and short cnemial processes, separated by a wide and rather deep valley. The ectocnemial process terminates in a rather blunt, down-turned hook, extending but very slightly above the summit of the bone. The latter slopes to the outer side, and presents a prominent, rounded, articular tubercle near the head of the femur, which may or may not be especially noticeable in this bone in other eagles. At the sides, as well as posteriorly, the summit bulges out over the shaft, being most thickened along its inner course, beyond which point a concavity occurs, bounded in front by the entocnemial process.

Turning to the fibula, it is to be observed that its shaft below the fibular ridge of the tibiotarsus is long and slender, being much compressed anteroposteriorly, opposite the middle third of the companion bone of the leg. Below this, it runs onto the shaft, and here the contact almost amounts to a direct fusion with it. At its lowest point it is not over 3.5 centimeters above the lower margin of the external tibial condyle. All diurnal Raptores possess fibulæ of greater or less length; especially do we find this to be the case in *Pandion*. Superiorly, in our subject, the fibula is much compressed from side to side, with its head produced posteriorly. Its entire summit, convex from before backward, is an articular facet for the outer condyle of the femur.

Pithecophaga possesses a rather large patella, which is elongate from side to side, in which direction the surface is convex, while posteriorly it is concave above and doubly concave posteriorly for articulation with the condyles of the femur. Inferiorly, the surface is limited and flat. Sometimes, as in the case of our present subject, there is a small, circular ossification in the tendon of the muscle, several millimeters below the true sesamoid of the knee joint; it occurs in both limbs.

Eagles exhibit very considerable variation in their leg bones, but more in the tibiotarsus than in the fibula. For instance, in the harpy the latter bone is more than a centimeter shorter than it is in the Philippine bird now being described, while at the same time the shaft is very conspicuously flattened from before backward; at the same time, this flattening is associated with a marked increase in the shaft's width. With respect to the fibula of the harpy, it broadens below the articular ridge, and is grooved for the passage of the muscle that passes over it (Plate VII, fig. 1). In the white-headed eagle the cnemial processes of the tibiotarsus are greatly reduced in all particulars, and to a lesser extent this is also true of the Korean eagle; the fibula is very long in the species.

With respect to the golden eagle (*Aquila chrysaëtos canadensis*), the bones of the leg are nonpneumatic for their entire length below the proximal extremities, the shaft of the tibiotarsus in this species being curved from end to end, the concavity being along the inner or mesial aspect.

Skeleton of the foot.—Plates X and XI. As already noted, the tarsometatarsus and other bones of the foot in this eagle are entirely nonpneumatic, while in some other forms the reverse of this is the case (*Haliæetus leucocephalus*). Irrespective of species the tarsometatarsus possesses the same general characters throughout the group, and its form is very characteristic. All this part of the skeleton in the harpy was left in the skin of the mounted specimen at the United States National Museum, so that no comparison can be made here along such lines with the corresponding bones in our subject. In the latter the bone has a length of about 12 centimeters and an average breadth of 2 centimeters. Its summit exhibits two shallow articular facets for the condyles of the tibiotarsus. An intercondylar tubercle stands between them on the anterior margin, the width of the surface being double its depth, while posteriorly is to be noted a hypotarsus of the usual aquiline type. This consists of a quadrilateral process standing out at right angles to the bone—its hinder border being considerably thickened—and its base opposite the inner articular concavity at the summit. Opposite the outer one is another process, it being stumpy and much aborted; between the two is a wide, shallow valley.

Posteriorly the shaft of this tarsometatarsus is smooth, broad above, and somewhat narrower distally. It is concaved throughout its entire extent, its margins being more or less sharpened, except where the accessory metatarsal is swung by ligament about a centimeter above the inner trochlea. The outer aspect of the shaft is flat, being broad at the middle third, and tapering somewhat to the ends. It is the posterior margin of this surface that forms the inner sharpened border of the posterior aspect alluded to above. Anteriorly the surface is much twisted upon itself, the upper half being concaved longitudinally and convexed for the rest of the extent, the two merging into each other. At the upper third, anteriorly, we note the usual twin perforations a short distance below the summit; and below them, to the outer side, is the elongate tubercle for muscular insertion.

Distally there are three very substantial trochleæ for the basal phalanges of the toes, the inner one being the largest and at the same time the lowest on the shaft. Slightly up on the shaft, between the outer and middle condyle, is to be noted the usual foraminal perforation present in nearly all birds; it transmits the flexor tendon of the outer toe and, it is said, the anterior tibial artery.

The accessory metatarsal is of considerable size, is flattened and somewhat twisted upon itself, and supports distally a very large, transversely disposed, trochlear facet; the latter is devoted to the articulation of the basal joint of the hallux, which is a digit of enormous power and strength, as will be appreciated through a glance at Plate X. Equally powerful are the joints and the talons of the anterior toes, the arrangement and proportions of which are upon the usual ornithic plan of the aquiline pes, with the osteological characters I have often described before, of existing forms as well as of fossil eagles.

CONCLUSIONS

Coming to the relationships of *Pithecophaga jefferyi*, with respect to other representatives of the same group and in the light of the osteological material above described and compared with its skeleton, I am of the opinion that its nearest ally, in so far as we are at present acquainted with the morphology of other eagles, is the harpy eagle (*Thrasaëtos harpyja*).

Sharpe[2] makes a very different disposition of this species; he places it between *Circaëtus* and *Spilornis*, of the Aquilinæ (Subfamily V); while the harpy eagle we find arrayed with the Buteoninæ (Subfamily III), following *Harpyopsis*, the next following Subfamily (IV) being the Gypaëtinæ (*Gypaëtus barbatus*). The osteology of *Pithecophaga* surely does not support this arrangement.

PREVIOUS PAPERS BY THE AUTHOR ON THE OSTEOLOGY OF THE EAGLES AND THEIR ALLIES

[Papers on the owls and the vultures are not included.]

1. On the ossicle of the antibrachium as found in some of the North American Falconidæ. *Bull. Nutt. Orn. Club* 6 (1881) 197–203.
2. On the free post-pubis in certain of the Falconidæ. *Auk* 3 (1886) 133, 134. 1 text figure.
3. Osteology of Circus hudsonius. *Journ. Comp. Med. and Surg.* 10 (1889) 126–159. 17 text figures.
4. A peculiar character referable to the base of the skull in Pandion. *Auk* 8 (1891) 236, 237.
5. Some comparative osteological notes on the American kites. *Ibis* VI 3 (1891) 228–232.
6. On a collection of fossil birds from the Equus beds of Oregon. *Am. Nat.* 25 (1896) 303–306. Plates.
7. Fossil birds from the Equus beds of Oregon. *Am. Nat.* 25 (1891) 818–821.
8. Tertiary fossils of North American birds. *Auk* 8 (1891) 365–368.
9. A study of the fossil avifauna of the Equus beds of the Oregon Desert. *Journ. Acad. Nat. Sci. Philadelphia* 9 (1892) 389–425, pls. 15–17.
10. On cases of complete fibulæ in existing birds. *Ibis* VI 6 (1894) 361–366, figs. 1, 2.
11. Some of the "outliers" among birds. *Pop. Sci. Monthly* 44 (1895) 760–780. 10 text figures (not osteological).
12. On the affinities of Harpagornis. *Trans. New Zealand Inst.* 28: 665.
13. Observations on the classification of birds. *Proc. Acad. Nat. Sci. Philadelphia* (1898) 489–499. Illustrated. (Osteology largely used.)

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[2] A Hand-list of the Genera and Species of Birds. London 1 (1899) 265.

14. An arrangement of the families and higher groups of birds. *Am. Nat.* **38** (1904) 833–856, text figs. 1–6. (Osteology largely used.)
15. Where the skeletons of American birds may be studied. *Auk* **26** (1909) 217–218.
16. Osteology of birds. *Bull. N. Y. State Mus.* **130** (1909) 367 pp. Education Department Bulletin No. 447. (This book contains many cuts and plates devoted to the osteology of the Falconidæ and has been particularly useful in studying the skeleton of the eagles.)
17. Review of the fossil fauna of the desert region of Oregon, with a description of additional material collected there. *Bull. Am. Mus. Nat. Hist.* **32** (1913) 123–178, pls. 9–43, figs. 1–578.
18. Further studies of fossil birds, with descriptions of new and extinct species. *Bull. Am. Mus. Nat. Hist.* **32** (1913) 285–306, pls. 51–59, figs. 1–94.

ILLUSTRATIONS

[All the figures are reproductions of photographs by the author made direct from the specimens.]

PLATE I

FIG. 1. *Pithecophaga jefferyi*, adult; right lateral view of the skull, natural size. All the bones of this bird figured on the plates are of two individuals. The specimens were received from Mr. R. C. McGregor, of the Bureau of Science, Manila, P. I.

2. The skull shown in fig. 1, seen directly from above, natural size.

PLATE II

FIG. 1. *Haliæetus leucocephalus*, white-headed eagle, sex?, adult; cranium, direct view from above, very slightly reduced. Median longitudinal diameter measures 11.1 centimeters in this specimen. No. 19278, United States National Museum collection. This skull belongs to the skeleton of the specimen used throughout this paper.

2. *Aquila chrysaëtos*, female, adult; cranium, direct view from above, very slightly reduced. Median longitudinal diameter measures 11.9 centimeters in this specimen. No. 18802, United States National Museum collection.

3. *Morphnus guianensis*, sex?, adult; cranium, direct view from above, very slightly reduced. Median longitudinal diameter measures 9 centimeters in this specimen. No. 18468, United States National Museum collection.

PLATE III

[All figures of Plate III natural size and from the same species, *Pithecophaga jefferyi*.]

FIG. 1. The six caudal vertebræ (*a* to *b*) arranged in normal sequence and viewed from above; *a*, anterior one of chain.

2. Pygostyle, right lateral aspect. Lower part pierced by a foramen.
3. Fifth cervical vertebra, seen from above.
4. Mandible, seen from above.
5. Anterior aspect of ninth cervical vertebra.
6. Trachea, twisted and distorted through drying; fragments of bronchial tubes at inner end.
7. The atlas, posterior aspect.
8. Anterior view of axis; neural spine directed downward.
9. Sclerotal circlets of the eyes; elements as they occur or are arranged in life.
10. Hyoid arches viewed from above, with larynx in situ; the latter removed at a point seen at the outer end of the trachea in fig. 6.

PLATE IV

Pithecophaga jefferyi; right lateral view of the trunk skeleton, including bones of the shoulder girdle, reduced about one-third. The pygostyle and the six caudal vertebræ preceding it have been removed.

PLATE V

Thrasaëtos harpyja, harpy eagle; right lateral view of the trunk skeleton, including bones of the shoulder girdle, reduced less than one-half. Length of sternum in the specimen equals 13 centimeters. No. 225806, United States National Museum collection; a specimen from Brazil.

PLATE VI

Pithecophaga jefferyi; trunk skeleton, seen upon direct dorsal view, with the shoulder girdle in situ, reduced about one-third. The pygostyle and the six caudal vertebræ preceding it have been removed.

PLATE VII

FIG. 1. *Thrasaëtos harpyja;* anterior aspect of the right tibiotarsus and fibula, slightly reduced. From the same specimen as Plate V.

2. *Thrasaëtos harpyja;* anconal aspect of left humerus, slightly reduced. From the same specimen as Plate V.

PLATE VIII

FIG. 1. *Aquila chrysaëtos,* golden eagle; anconal aspect of right humerus. No. 18802, United States National Museum collection. Length of bone, about 18.2 centimeters.

2. *Thrasaëtos harpyja;* anconal aspect of right humerus. From the same specimen as Plate V.

3. *Pithecophaga jefferyi;* anconal aspect of right humerus, reduced about one-third. Bone in life measures about 19.7 centimeters in length.

PLATE IX

FIG. 1. *Pithecophaga jefferyi;* left femur, posterior aspect. Extreme length of bone in specimen, about 13 centimeters. Bone entirely pneumatic.

2. *Pithecophaga jefferyi;* right tarsometatarsus and fibula, viewed on direct anterior aspect. Length of tarsometatarsus in specimen, about 23 centimeters.

3. *Pithecophaga jefferyi;* left tarsometatarsus and fibula, viewed on direct outer aspect.

PLATE X

Pithecophaga jefferyi; skeleton of the right foot, mesial aspect, natural size.

PLATE XI

FIG. 1. *Haliæetus leucocephalus;* skeleton of right foot, inner aspect, natural size. No. 19278, United States National Museum collection.

2. *Haliæetus leucocephalus;* skeleton of left foot, outer aspect, natural size. The same bird as in fig. 1.

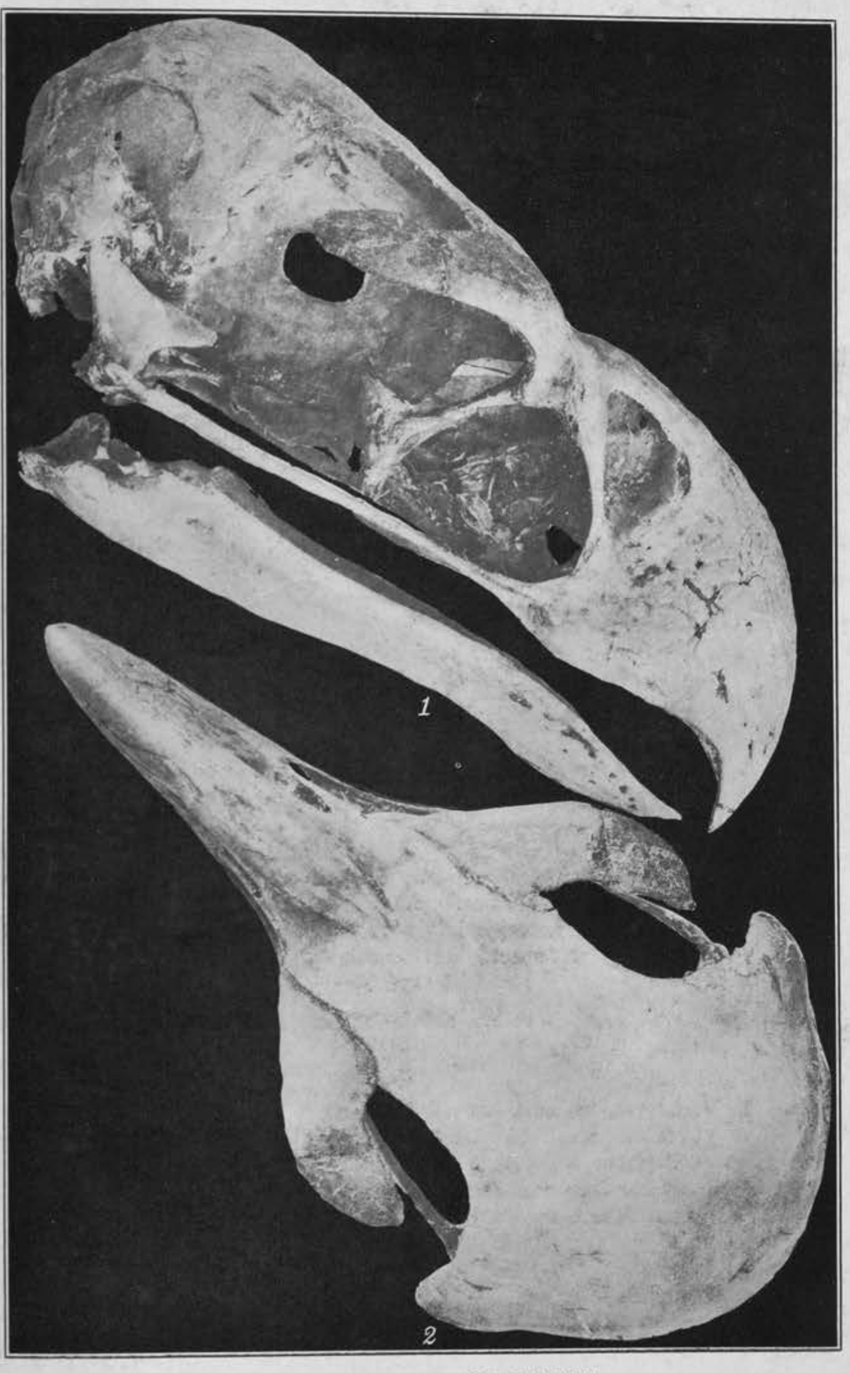

PLATE I. PITHECOPHAGA JEFFERYI.

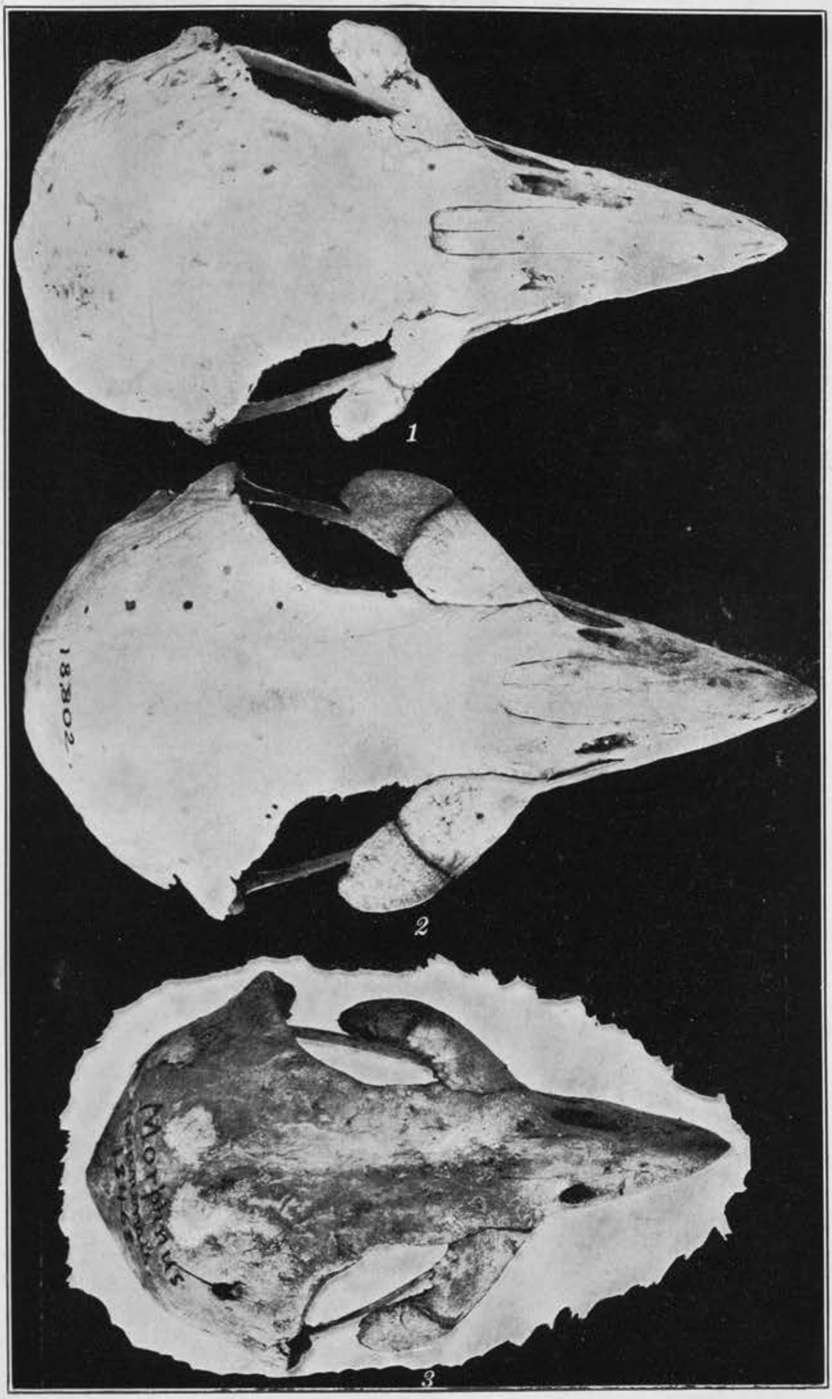

PLATE II. CRANIA OF THREE EAGLES.

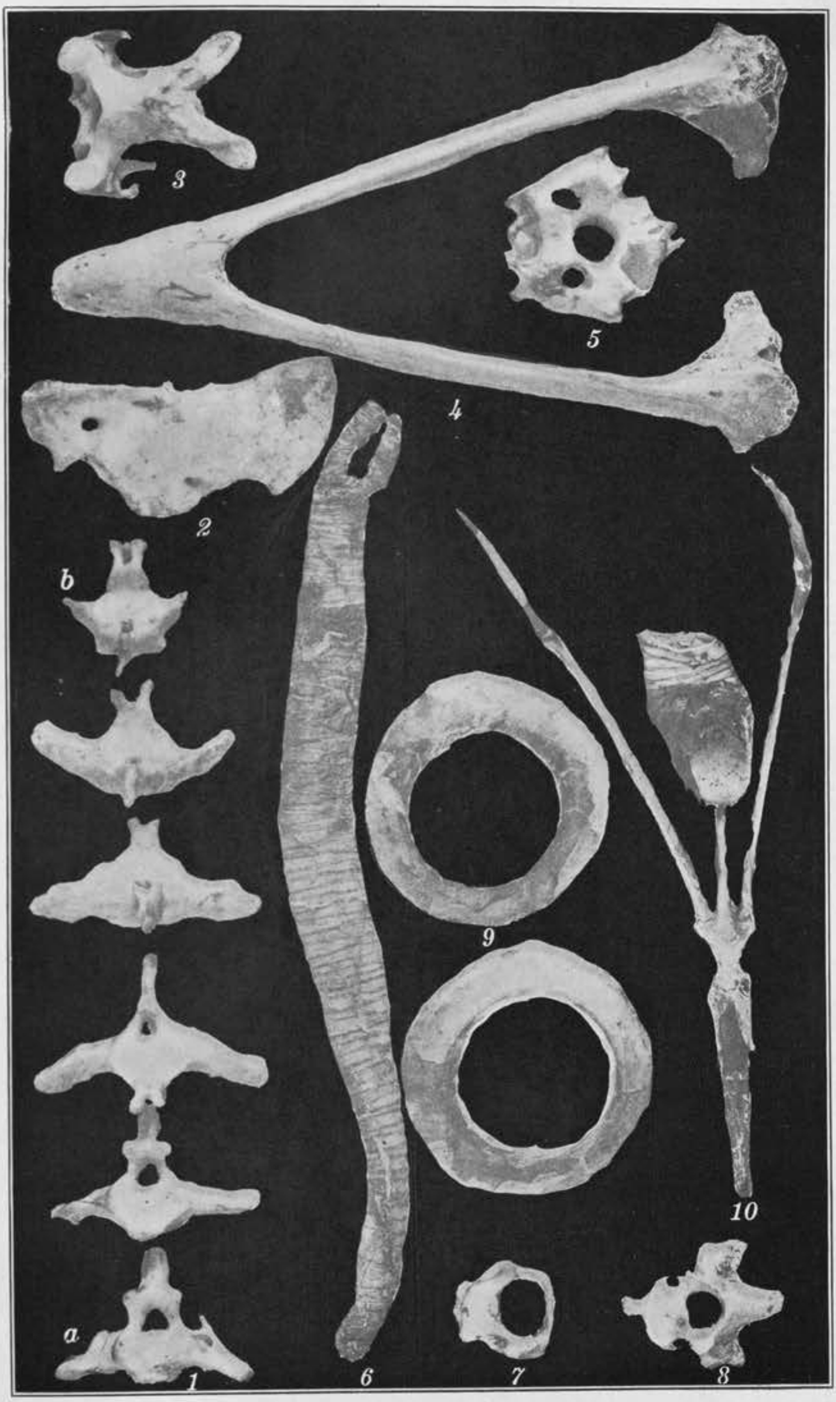

PLATE III. PITHECOPHAGA JEFFERYI.

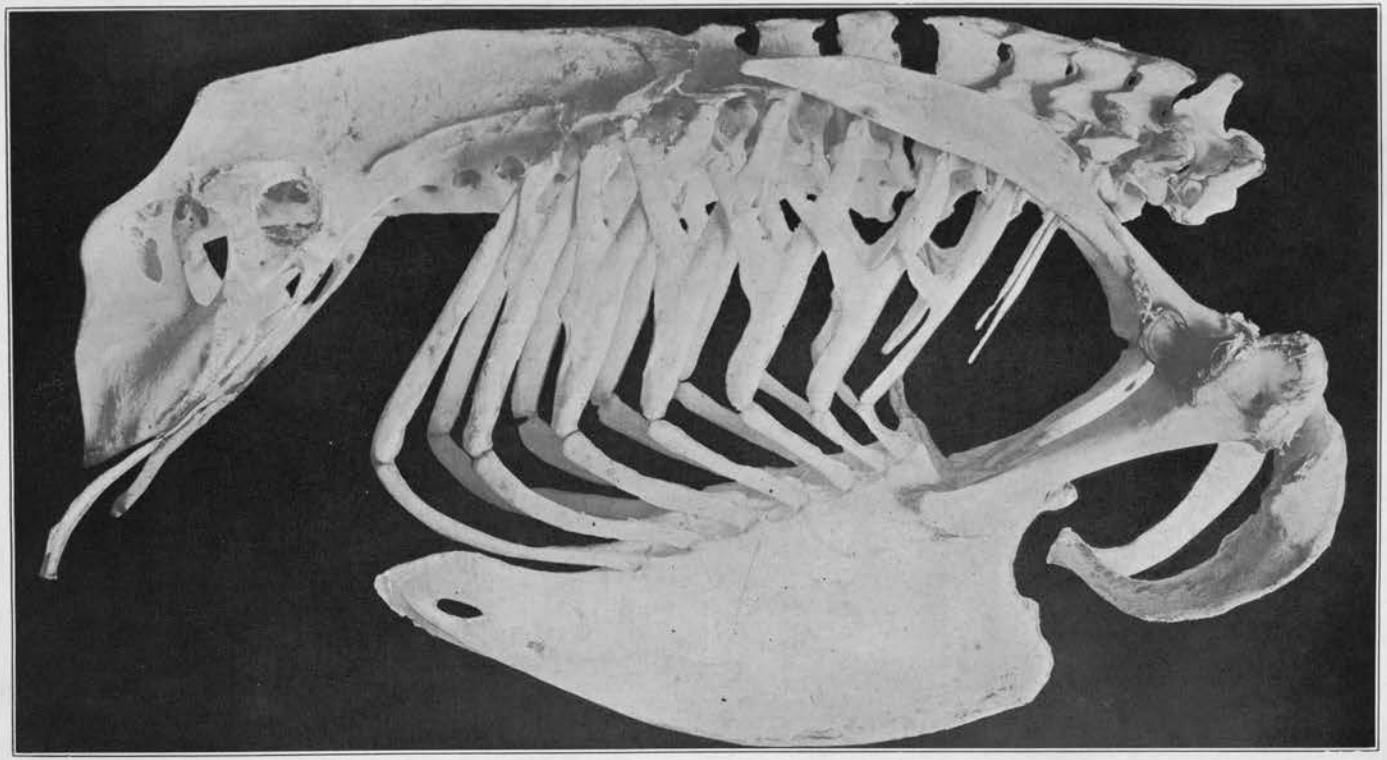

PLATE IV. TRUNK SKELETON OF PITHECOPHAGA JEFFERYI.

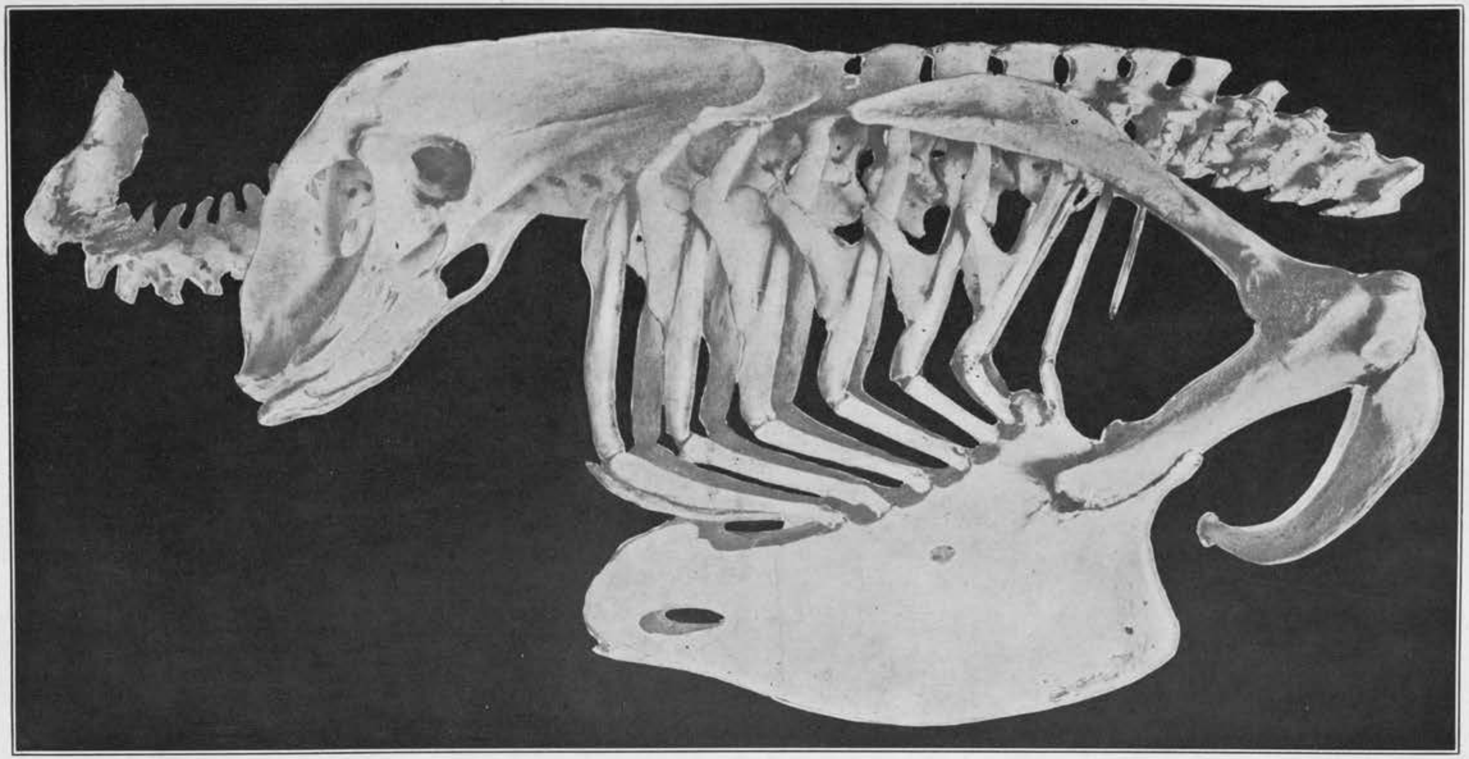

PLATE V. TRUNK SKELETON OF THRASAËTOS HARPYJA.

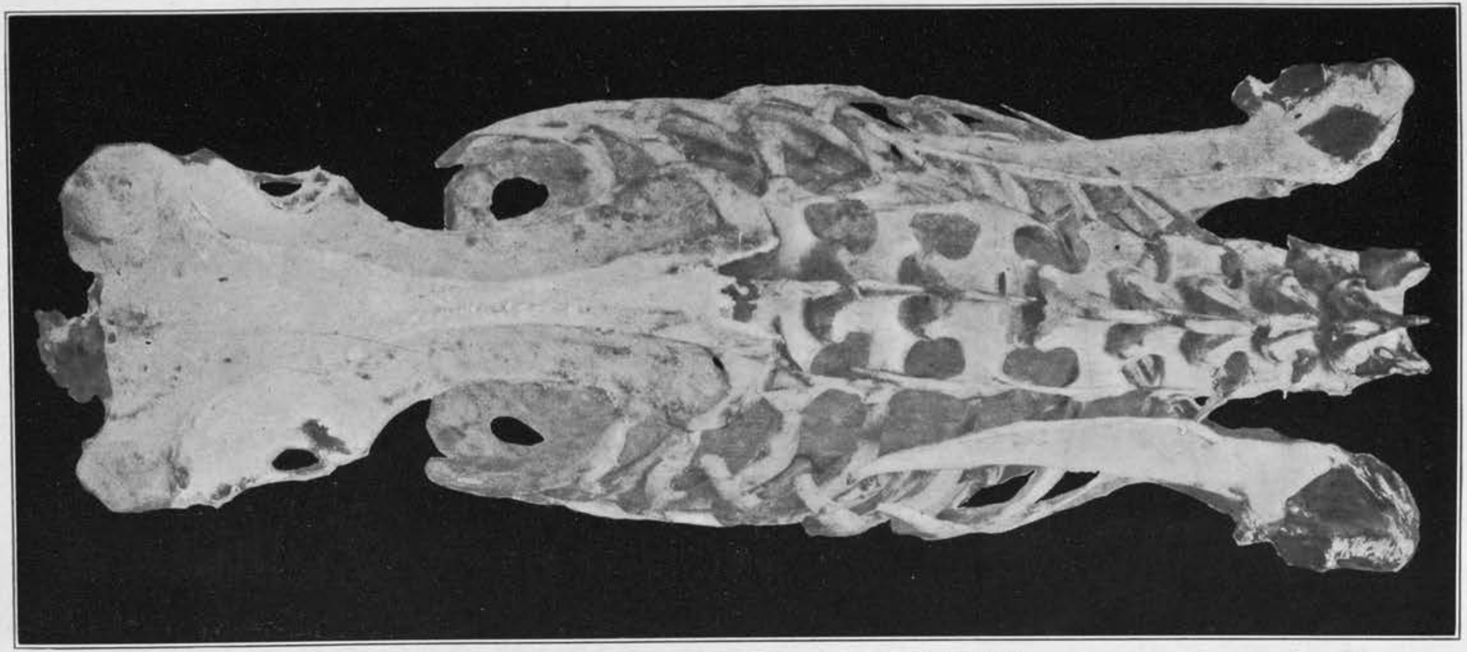

PLATE VI. TRUNK SKELETON OF PITHECOPHAGA JEFFERYI.

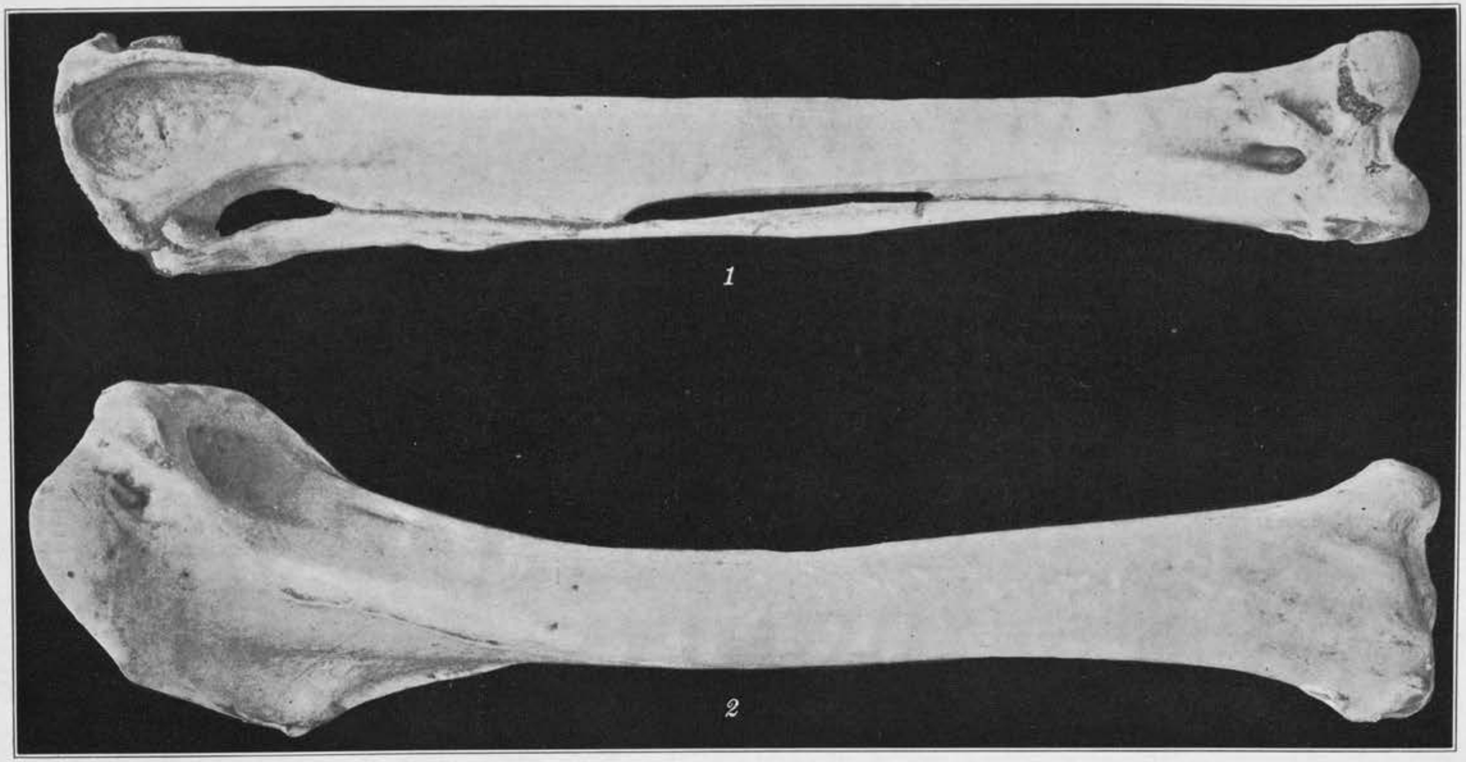

PLATE VII. THRASAËTOS HARPYJA.

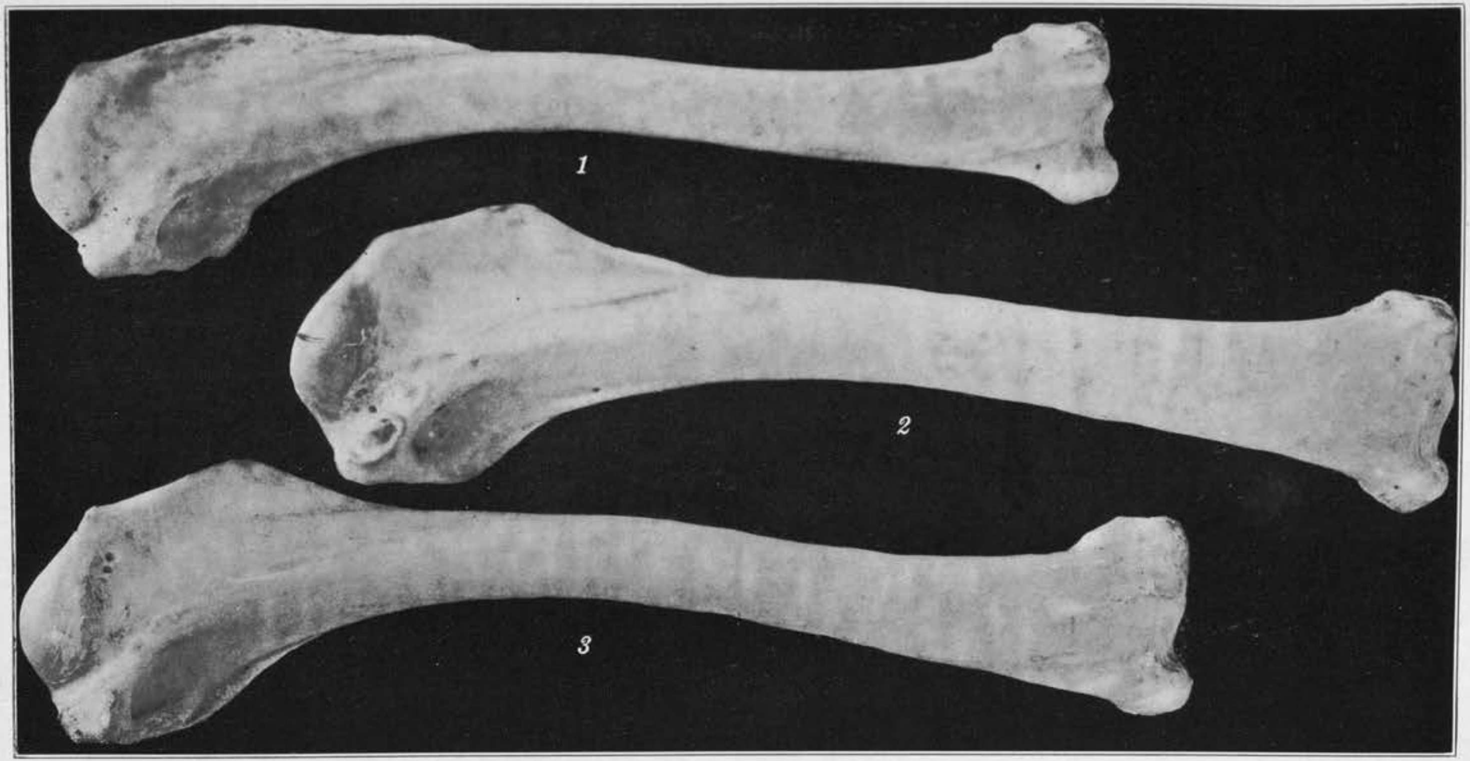

PLATE VIII. HUMERI OF THREE EAGLES.

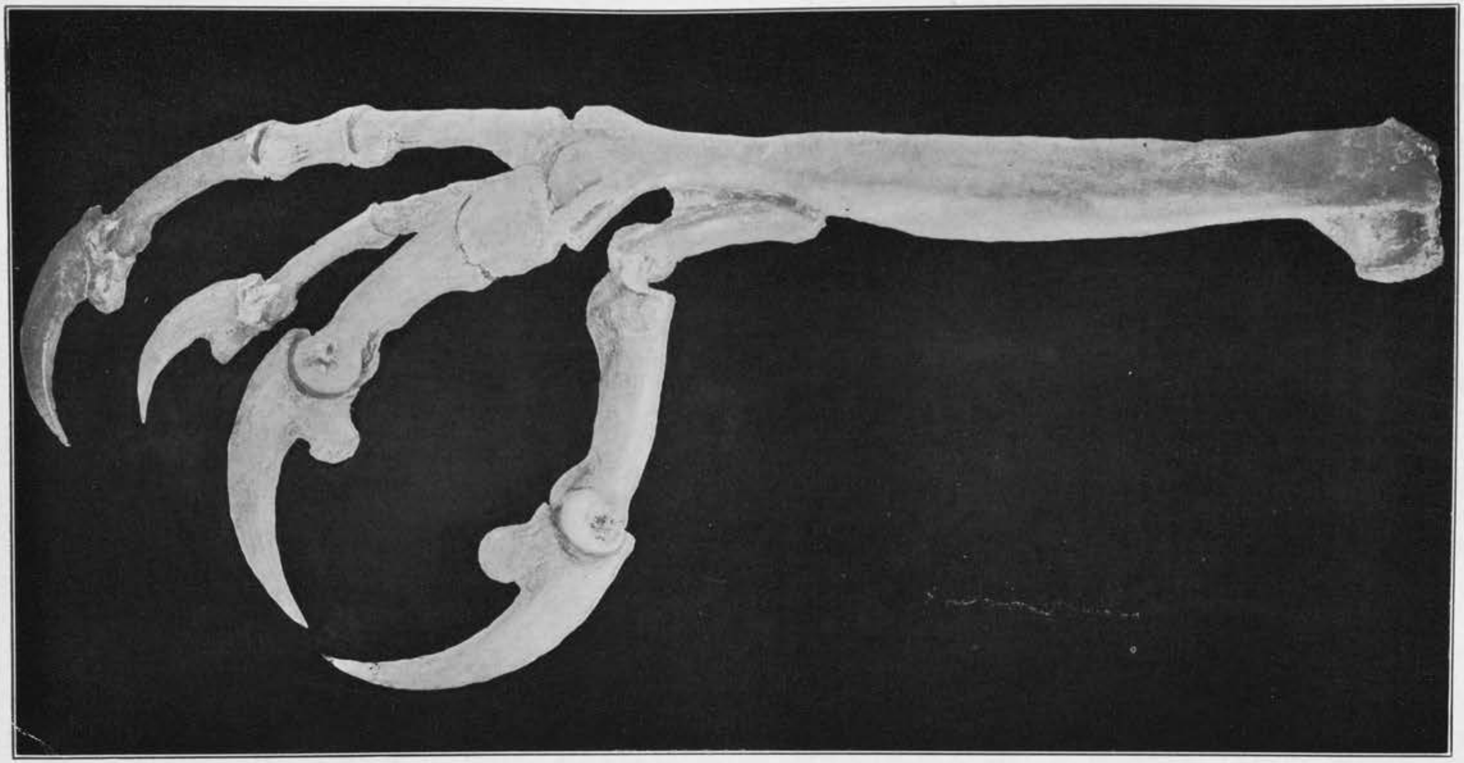

PLATE X. FOOT OF PITHECOPHAGA JEFFERYI.

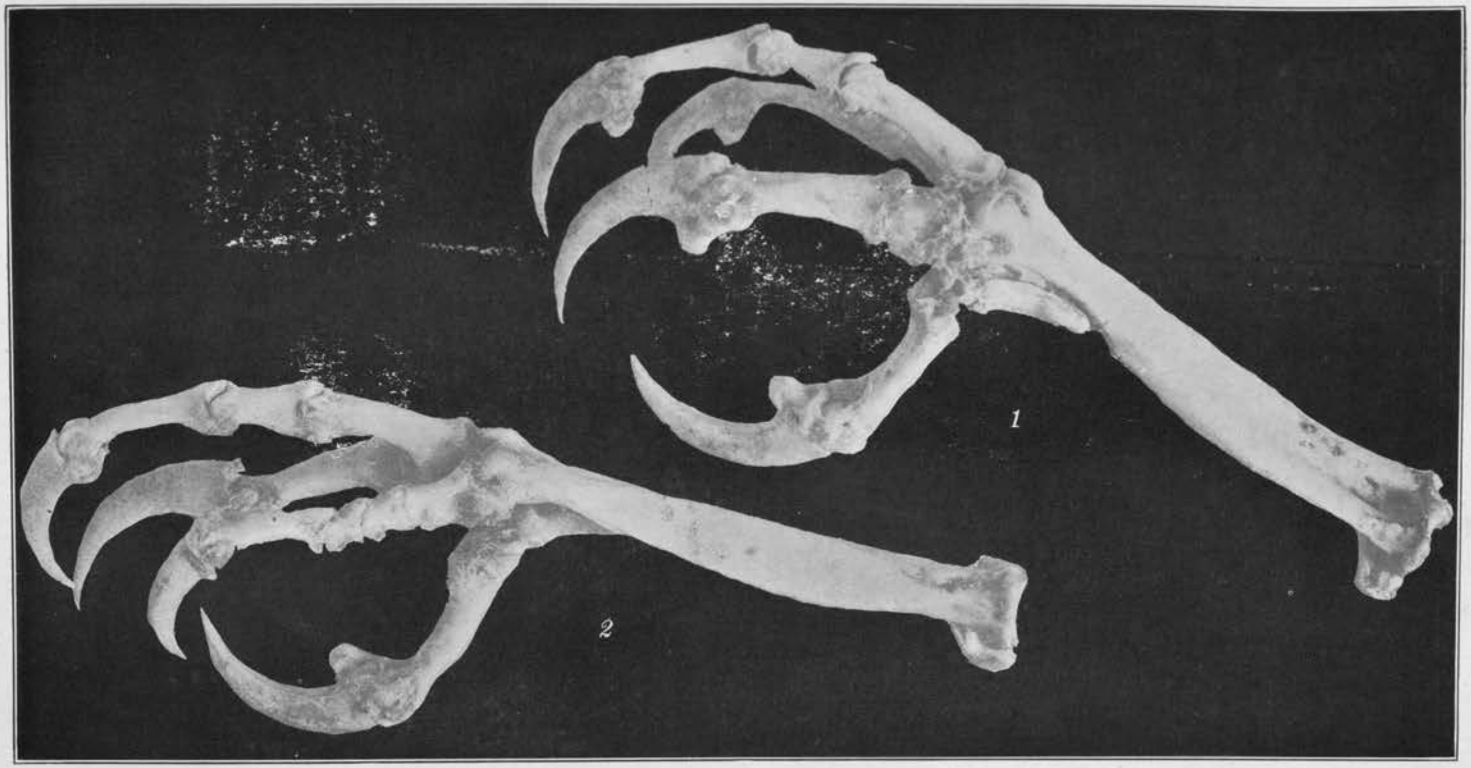

PLATE XI. FEET OF HALIÆETUS LEUCOCEPHALUS.

GENERAL FACTS IN THE BIOLOGY OF PHILIPPINE MOUND-BUILDING TERMITES

By Leopoldo B. Uichanco

Of the Department of Entomology, College of Agriculture, University of the Philippines, Los Baños

FOUR PLATES

The mound-building species of Philippine termites so far known are all members of the genus *Termes*. They are common in rural and suburban places; and in caiñgin fields they are left undisturbed, although undoubtedly a menace to farming operations, both because they are always in the way and because they are prolific sources of severe anay[1] infestation. The tao tolerates the nests, not because he is too lazy to dig them out, but because a tradition current among Filipino peasants makes the *nuno*[2] the regular occupant of the mound. The nuno is a sort of wood-inhabiting spirit, believed to be normally invisible; he, however, occasionally appears to us mortals in the form of a small, unsightly, evil-looking old man, wearing a large *salacot*.[3] His every desire is a wicked one. He takes pleasure in causing human suffering; and to injure him, even though accidentally, means sickness, and often death, to the offender.

The termite mounds found in the Philippines do not reach the proportions of those met with in some other countries. In Australia, for example, termite mounds grow so large that they often appear to the traveler to be huge earthen towers. Old termite mounds in the Philippines very rarely reach a height of two meters. They generally approach a round-topped, conical shape, and are usually free from green vegetation, although they are occasionally found covered all over with a thick mat of cogon or low shrubbery. Sometimes a mound is built around or against a large tree trunk, in which case its shape becomes very irregular. The outer wall of the nest is remarkably compact, considerable force being necessary to break it open with a mattock. The main constituent of this wall is very fine clay, which has probably been made firm and sticky by admixture with certain substances from the bodies of the termites. Mounds over which a large heap of grass or sticks had been burnt were, on opening, observed to have all their inhabitants, including the delicate nymphs and the eggs, absolutely unaffected by the heat.

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[1] Local name for the termite, or white ant.

[2] Tagalog for grandfather.

[3] A native helmet, usually made of bamboo or palm leaves, and rattan.

Beneath the thick outer crust of clay are the "fungus gardens," composed entirely of a mixture of fine pellets of woody excreta and plasterlike material, which have passed out of the alimentary canals of the workers. In a typical anay mound these gardens occupy the greater part of the inner cavity; compact slabs of moist clay, with numerous irregular passageways running through them, form the partitions and, at the same time, the supports of the gardens. Each garden is composed of numerous vertical galleries formed by the intersection of the walls; the general appearance is that of a sea coral, with the upper convex margin of each partition neatly finished and the lower part either unfinished or made rugged by being bitten off. As the name indicates, the termites utilize the gardens in the cultivation of certain species of fungi, or mushrooms, to be more specific. They regularly harvest the "buttons" of the fungi, as soon as they appear, for use as food. At certain seasons of the year, during the rainy months, the mushrooms break through the outer wall of the nest and develop into full-grown plants. These mushrooms are a common sight in the regions about Los Baños on the mounds, or on the surface over underground anay nests; and they are much relished as an article of food by everybody who eats them. The local farmers know them under the general name of *mamunso*.[4]

Several theories have been proposed in connection with the periodical appearances of this mushroom. One explanation is that on the advent of a more favorable season, the fungi in the termites' gardens become so numerous that a certain number find a chance to escape and develop into perfect mushrooms before the workers have a chance to harvest the "buttons." Another is that the termites purposely allow the mushrooms to develop into mature plants in order to furnish seed for the following season. The galleries of the fungus gardens and the network of tunnels in the intervening slabs of clay also serve as nurseries, where the eggs and the young nymphs are taken care of. An upright, irregularly shaped pillar of clay, which forms the core of the nest, serves the double purpose of supporting the series of fungus gardens and of being the main prop that prevents the outer shell of the nest from collapsing.

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[4] Of or pertaining to the mound (Tagalog).

At least six different forms of adult individuals are present in the nest; namely, the king, the queen, the large and the small workers, and the large and the small soldiers. Each caste has a distinct function in the nest; and, due to the similarity of the termites to the true ants in community economy, they are often termed "white ants." The various castes present in each nest are the offspring of a single pair, which has settled down and mated after swarming.

The swarming of winged termites occurs after sunset or late in the evening, usually during the months between May and September. The swarms are composed of individuals of both sexes, the males for some reason far outnumbering the females. Several counts made on certain swarms of *Termes* (*Macrotermes*) *philippinensis* Oshima, in 1915, gave an average of less than five females to a hundred males. These swarms come from well-established anay nests where, at certain seasons of the year, winged individuals are produced. On certain nights, probably as a result of favorable climatic conditions, large swarms of winged termites are observed to occur at the same time in widely separated localities; for example, the campus of the College of Agriculture and the municipalities of Los Baños and Calamba. These insects are exceedingly feeble fliers and, for this reason, cannot travel far on their wings; they could not possibly have reached these very distant places from a nest located at any one spot. The more logical inference is that there occurs a simultaneous swarming from nests over a large area.

An enormous number of individuals composes a swarm; but a great many of them perish in their conjugal flight by being preyed upon by their numerous enemies—principally bats, birds, lizards, and ants. After shedding their wings, the couples run about, the male following the female by clinging fast with his mouth parts to the posterior extremity of her body, until they finally succeed in locating a fit spot in which to build their nest. This is usually under a stone or a piece of wood on moist ground, where they dig a small hollow in which they establish themselves. Some observers maintain that a group of wandering workers of the same species must fall in the way of each newly mated couple and help it establish the colony; but more sound evidence is necessary definitely to prove this assertion. The paired individuals coming down from the swarm and building a nest go for a considerable length of time without food. About five days after starting the new home, the female begins to lay from one to five eggs, at intervals of two or three days. It takes the eggs about a month to hatch, and the adults that develop therefrom are mostly workers, only a very few soldiers being produced. Sexual individuals are not produced until later, when the colony is already well established. The nymphs of soldiers do not exhibit the characteristic appearance of their respective mature forms until about the last instar, or immediately before the insect reaches the adult stage. Nymphs of the sexual caste are larger than those of either soldier or worker and are easily distinguished by the presence of wing pads on those areas of the body where the full-grown wings are to develop later. The nymphal stage of the soldiers and workers lasts about a month; no definite observation has as yet been made in connection with that of the winged form. In about three months after the establishment of the nest, a sufficient number of small workers has been developed to start the work on a fungus garden and on the preliminary construction of the new mound which is to become the permanent home of the colony.

In a well-established nest the royal chamber is located a little below the level of the surface of the ground. It is a hollow, plano-convex chamber, with thick, irregular, clay walls and numerous passageways connecting with the adjoining parts of the nest. Within the chamber are the king and the queen, attended by a large bodyguard of soldiers and workers. Occasionally, two queens are found occupying the same chamber in a nest; but in all cases not more than one male is present. The king has not changed his appearance since he first came down from the nuptial flight; he is still very lively and is likely to slip away and escape detection unless some care is exercised in removing the royal chamber from the nest. On the other hand, the queen has changed considerably. Her abdomen is much engorged with eggs; and the abdominal tergites and sternites, once closely connected, are now situated far apart, with their connecting membranes greatly distended. The insect at this time presents a characteristic sausagelike appearance. Her activity is restricted in so far as locomotion is concerned; and she is now entirely helpless—actually a prisoner in her own cell. The workers feed her, clean her body, and look after her personal comfort. Her abdomen exhibits a succession of peristaltic movements, attended by a continuous discharge of more or less elliptical eggs. A full-grown queen lays eggs at the rate of thirty to sixty a minute. The workers remove the eggs immediately after they are extruded and carry them away to be taken care of in the nurseries.

The original king does not live long, being probably replaced many times during the existence of the colony. The queen's life has been estimated to last about twenty years. Certain species of termites insure the perpetuation of their colony by providing for a substitute queen, sometimes designated neoteinic. The latter is distinguishable from the true queen by the absence of any indication of her having ever attained the power of flight. She is fully as capable of reproduction as the true queen, but does not live quite so long.

The soldiers and the workers are asexual individuals. They have no external indication of the organs of sight and never develop wings. They avoid the light and build protective covers wherever they go, though there is a species of black termites[5] which travels readily in the daylight through forests and in open places when necessary. Numerous passageways radiate in all directions, under or upon the surface of the ground, from their nests to the objects of their attack—old logs, living tree trunks, house posts, fences; in fact, all kinds of ligneous materials that may come within their reach. Accompanied by a comparatively small number of soldiers, a number of workers set out upon their work in regular processions, usually under cover of dirt tunnels. The others that remain at home are on duty attending the queen, the eggs, and the young; enlarging the mound; harvesting the crops; protecting the nest against intruding enemies (of which the worst is a species of red ant, *Solenopsis geminata* Fabr., very frequently found living in large colonies within easy reach of the mounds); and keeping the mound in a healthy and sanitary condition. To keep their nest clean, the termites maintain, or otherwise encourage, in their colony a force of scavengers, often termed "guests," consisting of beetles, earwigs, cockroaches, spring-tails, and myriapods, which continually rid the premises of waste materials.

Communication among the termites is undoubtedly carried on by means of their senses of touch and of smell. They have a remarkable ability to locate the different places in the perfectly dark nest, and can start on long journeys and search out their various necessities with an admirable degree of precision. A hole made in a tunnel or in the outer crust of the nest is sure to bring in response the soldiers' powerful mandibles protruding from within, around the edges of the break, while the workers come in succession, each carrying a small pellet of materials for repair. The workers, architects by nature, know just when a portion of their structure is not strong enough to prevent collapse, for in tunnels where the walls span out very wide to the two sides, they reënforce the weaker spots with supporting pillars of prepared earth. In a termite colony each worker is apparently his own boss; yet no confusion or trouble arises as a result, for they all seem to think, plan, and work together in perfect unison, as though they were interrelated units of one single organism—a marvelous example of the true communistic society where every effort of every individual is directed toward the general welfare, the good of the race.

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[5] Probably not a mound-building species.

ILLUSTRATIONS

PLATE I

FIG. 1. A typical termite mound, or *punso*, in the Philippines.

2. Vertical section of the mound shown in fig. 1. Note the thickness of the outer wall and the central upright pillar of clay. The fungus gardens are arranged between this pillar and the outer crust.

PLATE II

FIG. 1. A layer of fungus gardens, showing arrangement in the nest.

2. Royal chamber, top view.

3. Royal chamber, vertical section through the middle portion. The flat floor and concave roof are characteristic features of the chamber.

PLATE III

FIG. 1. Fungus garden, top view, with large fungus "buttons" probably preparing to break through the outer wall of the nest and develop into full-grown mushrooms.

2. A portion of the slab of compact clay from the central upright pillar of the nest, showing openings to the passageways of soldiers and workers.

3. A typical fungus garden. Top view, on the right, showing the characteristic even smoothness of the edges of the walls; nether aspect, on the left. The rugged condition of the edges of the walls is natural and very characteristic.

PLATE IV

FIG. 1. Tunnel of prepared earth built by workers on dead wood to protect them from light in their expeditions.

2. Work of termites on structural bamboo.

3. Work of termites on Oregon pine.

4. The royal couple and retinue. The big, sausagelike individual is the queen, with a batch of freshly laid eggs near the tip of the abdomen. The individuals with large shiny heads and long mandibles are soldiers. All the rest are workers.

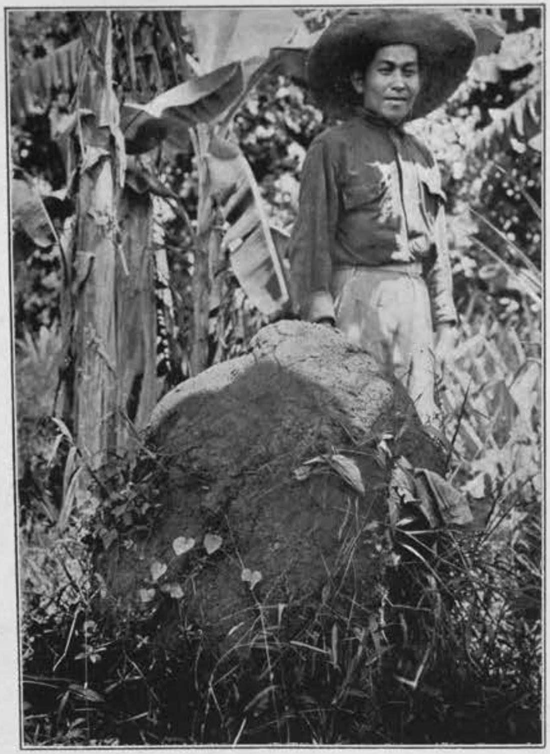

Fig. 1. A typical termite mound.

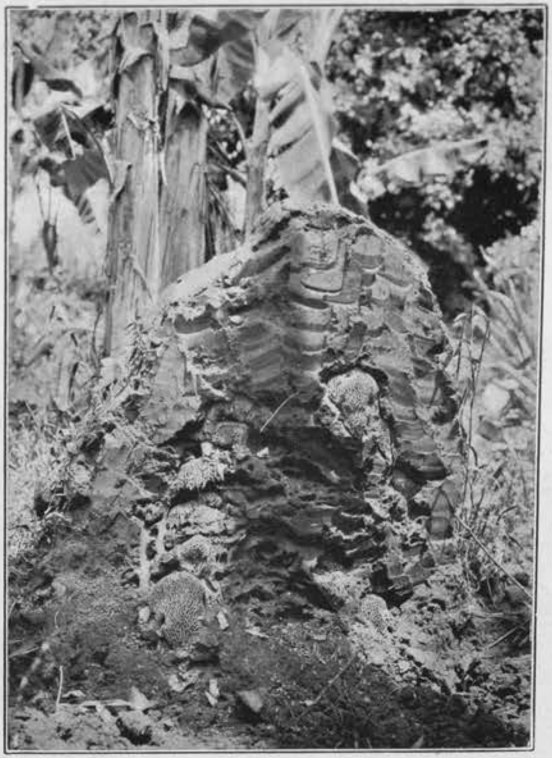

Fig. 2. Vertical section of mound.

PLATE I.

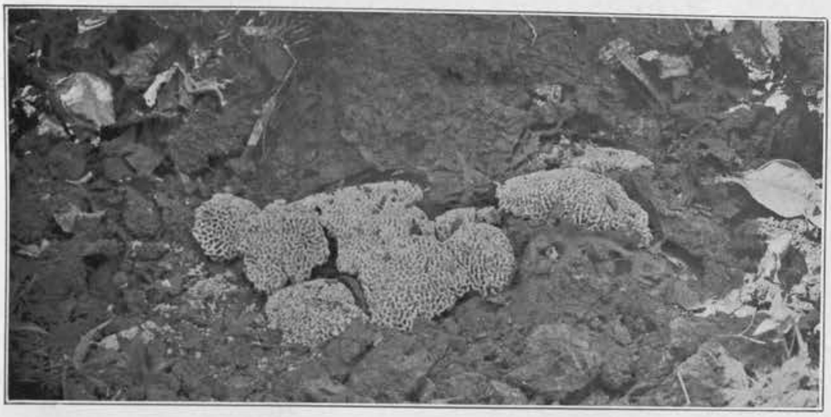

Fig. 1. A layer of fungus gardens.

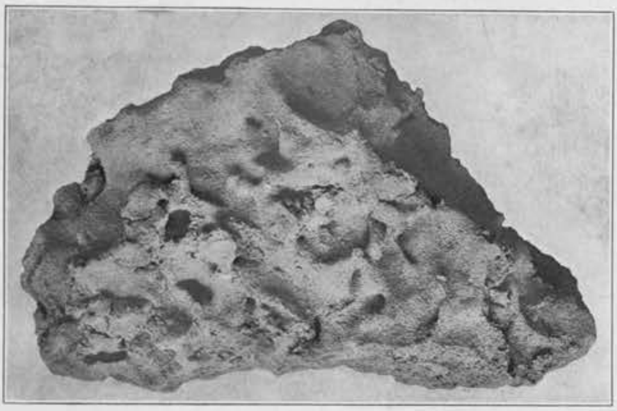

Fig. 2. Royal chamber, top view.

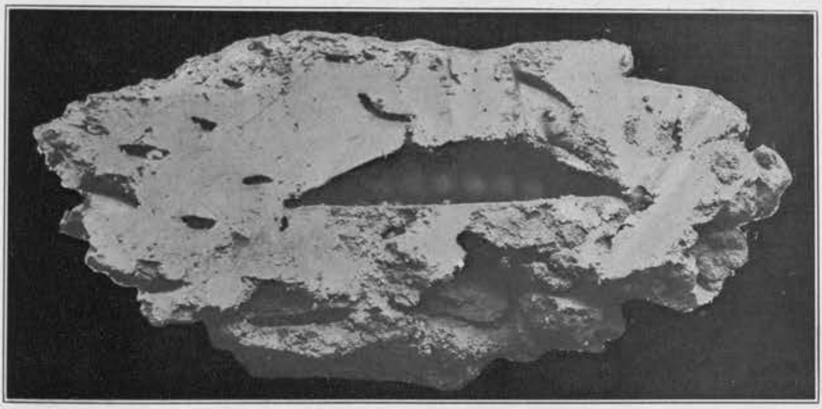

Fig. 3. Royal chamber, vertical section.

PLATE II.

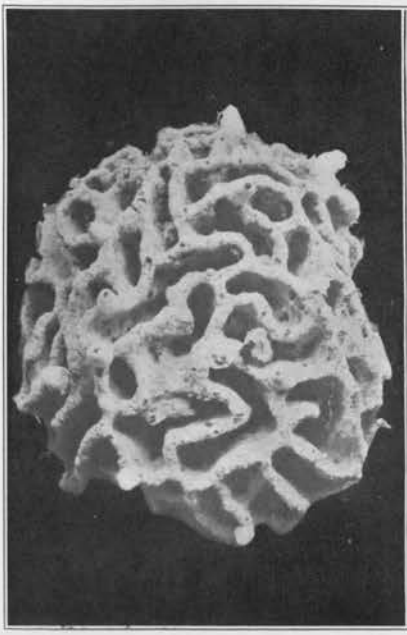

Fig. 1. A fungus garden.

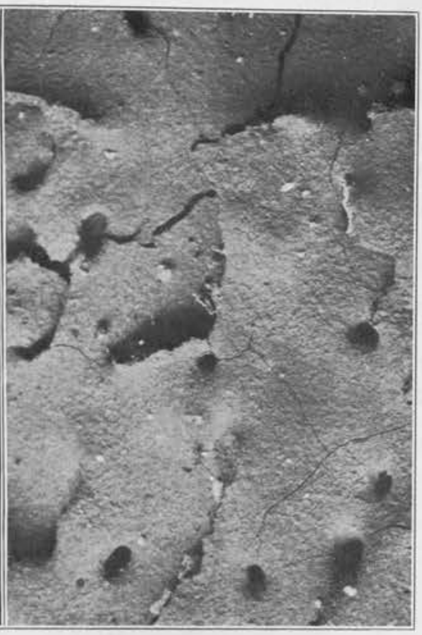

Fig. 2. The royal chamber.

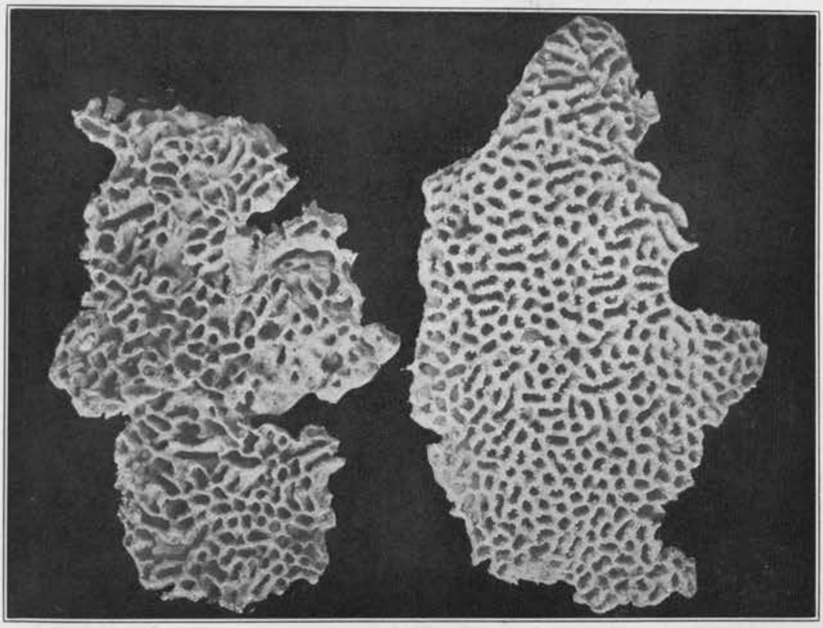

Fig. 3. A typical fungus garden.

PLATE III.

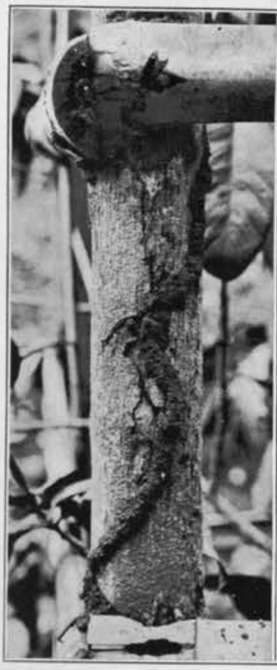

Fig. 1.

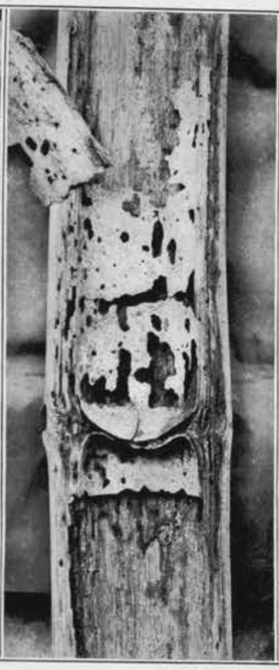

Fig. 2.

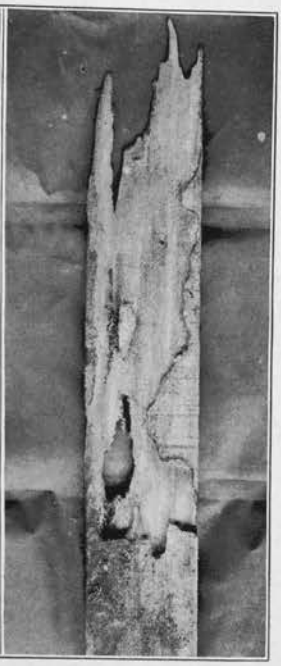

Fig. 3.

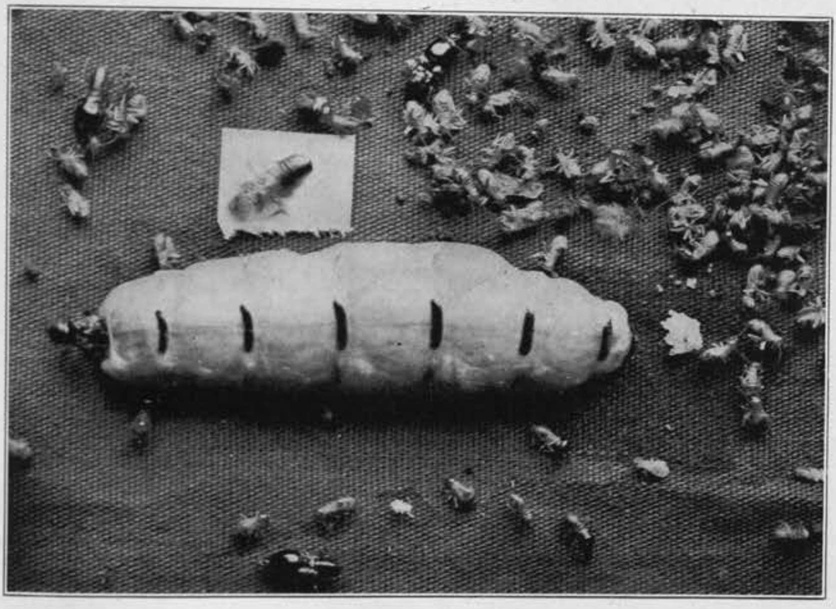

Fig. 4. The royal couple and retinue.

PLATE IV.

THE MALAYAN MACHÆROTINÆ (CERCOPIDÆ)

By C. F. Baker

Of the Philippine College of Agriculture, Los Baños

THREE PLATES AND ONE TEXT FIGURE

The insects composing this group, remarkable in both structure and habit, have been latterly considered to form a subfamily in the Cercopidæ. When only *Machærota* was known, this seemed doubtful, but through other recently described genera the relationship is much more evident. The habits of members of this group distinguish them from all other Cercopidæ, and from most other insects as well; since the nymphs live in calcareous tubes, of curious form characteristic of the various species, and possess remarkable structural adaptations to life in these tubes, which remain attached to their special food plants.

Had the Enderleiniini not been included in the group, the Machærotinæ would have been easy to define, the remarkable scutellar appendage and characteristic structure of the tegmina being diagnostic. Schmidt defined the Enderleiniini as having the scutellum without spinous appendage, but elongate caudad and reaching or exceeding the apex of the abdomen. However, *Machæropsis*, as illustrated by Lallemand,[1] has a scutellum not reaching half the length of the abdomen, though in structure otherwise it appears to be somewhat machærotine; and one of Schmidt's most recent genera, *Modiglianella*, is very close to cercopid genera like *Quinquatrus* Distant and *Hindola* Kirkaldy (=*Carystus* Stål). It seems, arguing from structure alone, that the tribe Enderleiniini should be transferred to the Aphrophorinæ, which already includes far more diverse elements, the latter subfamily to be divided into a number of coördinate tribes.[2] This would not preclude the possibility of the true Machærotinæ being offshoots from Enderleinia-like forms. The present paper will deal only with the true Machærotinæ known from Malaya.

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[1] Cercopidæ of the Genera Insectorum (1912).

[2] In Fauna Brit. India, Rhynch. 6 (1916) 184, Distant describes a new genus, *Conditor*, of which he says, "Allied to *Machæropsis*." It does not, however, belong in the same tribe with *Machæropsis* (Enderleiniini), but is apparently closely related to *Pachymachærota* in the Machærotini.

The first species known in this group was *Machærota ensifera* Burmeister, described in 1835, from Manila. In 1907[3] Schmidt presented a monograph of the group, separating it into four tribes and recognizing eight genera. In 1912 the same[4] author added two genera, *Modiglianella* from Sumatra and *Neuromachærota* from German East Africa. Two Australian genera, *Polychætophyes* and *Pectinarophyes,* were described by Kirkaldy[5] in 1906, though these were not included in Schmidt's monograph.

Machæropsis Melichar is known only from Ceylon, *Enderleinia* Schmidt only from Togo, and *Pachymachærota* Schmidt from Australia and Sumba. Therefore, half of the known genera and the larger proportion of the known species come from the Malayan Region. Since this region, as well as Australasia, is but little explored as to the Homoptera, the known forms of this group probably represent but a small part of the genera and species in existence. So far, *Machærota* appears to be the only genus of wide distribution, species of it being found from India (with Ceylon and Andamans) and China, to the Philippines, Malaya, and Flores. It will undoubtedly be found still farther to the southeast, through the Moluccas. New Guinea will almost certainly yield interesting members of the group.

In the present paper, two new Philippine species are added to *Machærota; Grypomachærota* is shown to be represented by two new species in Borneo and to occur in Penang; and *Maxudea* is for the first time recorded from the Malay Peninsula.

The Machærotinæ present a most interesting field for anatomical study. The sclerites of the thorax are deeply and sharply marked, and present most remarkable forms. A sounder classification will undoubtedly be possible when these have been exhaustively studied. The hind femora (? in *Maxudea*) usually have a strong tubercle beneath at base. The membranous appendix of tegmina is usually transversely fluted. The impressed horizontal suture in front of ocelli is the actual anterior margin of vertex, the sutures passing forward from its extremities being the lateral margins of frons. The upper portions of the cheeks are thus distinctly superior. It thus results that the projection of the head in *Grypomachærota* and *Sigmasoma* is entirely referable to the frons. For purposes of description in this paper, however, the entire superior surface of the head between the eyes is termed vertex.

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[3] Ent. Zeitg. Stettin 68 (1907) 165–200.

[4] Ent. Zeitg. Stettin 73 (1912) 173–178.

[5] Bull. Haw. Sugar Plant. Exp. Sta. 1 (1906) 384–386.

Subfamily MACHÆROTINÆ sensu stricto

Key to the tribes.

a^1. Body slender; scutellum arched and with a distinct dorsal furrow; pronotum without produced lateral angles.
  b^1. Frons not produced above; hind tibiæ without a tooth.... Machærotini.
  b^2. Frons acutely produced above; hind tibiæ with one tooth..Sigmasomini.
a^2. Body very thick and stout; scutellum nearly flat and with dorsal furrow subobsolete; pronotum with lateral angles produced into high thin laminæ .... Maxudeini.

Tribe MACHÆROTINI

This tribe includes but one Malayan genus, so far as known.

Genus MACHÆROTA Burmeister

Key to the species.

a^1. Claval vein apically forked.
  b^1. Body of scutellum not high arched posteriorly, its greatest depth much less than length; vertex anteriorly broadly rounded; spatulate scutellar furrow about half length of body of scutellum (Plate I, figs. 1 and 9)... M. notoceras Schmidt.
  b^2. Body of scutellum high arched posteriorly, its greatest depth as seen from side about equaling length; vertex anteriorly subangulate; spatulate scutellar furrow much more than half length of body of scutellum (Plate I, figs. 2, 3, and 10; Plate II, fig. 1). M. philippinensis sp. nov.
a^2. Claval vein simple.
  b^1. Median cell short and broad; length of vertex far less than width between eyes posteriorly; spatulate scutellar furrow less than half length of body of scutellum.
    c^1. Length of body of scutellum distinctly greater than that of pronotum; length of scutellar spine less than once and a half the length of body of scutellum; ocelli nearer to median line than to eyes (Plate I, figs. 4, 5, 11, and 14; Plate II, figs. 3 and 4).. M. ensifera Burm.
    c^2. Length of body of scutellum subequal to that of pronotum; length of scutellar spine a little less than twice length of body of scutellum; ocelli as near median line as to eyes (Plate I, figs. 6 and 12; Plate II, figs. 5, 6, and 13).................... M. luzonensis Schmidt.
  b^2. Median cell long and narrow; length of vertex subequal to width between eyes posteriorly; spatulate scutellar furrow much more than half length of body of scutellum (Plate I, figs. 7, 8, and 13; Plate II, figs. 2, 7, and 10)... M. fusca sp. nov.

In *Machærota notoceras*, *M. philippinensis*, and *M. ensifera* the sharp upper border of the scutellar spine is extended into the scutellar furrow as a sharp median carina to half its length, whereas in *M. luzonensis* and *fusca*, it scarcely enters this furrow. All of the species possess a small, thin, semitranslucent, decolored spot on the upper border of the spine near its base. The depth of coloring is widely variable in all of the species, and the males are always smaller and darker than the females. Structural characters only should be depended upon for classification. What appear to be the normal color forms are described in the following pages.[6]

Machærota notoceras Schmidt.

Machærota notoceras SCHMIDT, Ent. Zeitg. Stettin 68 (1907) 192.

This species is common on Penang Island, Wellesley Province, Straits Settlements.

Machærota philippinensis sp. nov.

Female.—Length to end of abdomen, 4.5 millimeters; to ends of tegmina, 6; to end of spine, 7.

Color chocolate; frontal ridge and apex of frons piceous; sides of frons with ten horizontal yellowish stripes, these with numerous short, coarse, appressed white hairs; second antennal joint rufous with white distal border; sides of body of scutellum with curved ivory-white areæ, reaching from anterior lateral angles to anterior extremity of scutellar groove; the thin margins of scutellar groove alternately black and yellow spotted; a few minute black dots on posterior lateral walls of scutellar body; posterior border of scutellar body below spine ivory-white, the stramineous spine separated from brown scutellar body by an irregular piceous border. Veins of tegmina stramineous with scattering piceous dots, the tegmina suffused with very pale stramineous, the costa brown near base. Abdominal dorsum black, first tergite yellow; venter largely piceous; tibiæ and tarsi paler brown than femora.

Frons very minutely punctate-rugose, near clypeus and with clypeus, coarsely punctate-rugose; median ridge broad and strong on upper half of frons; vertex sculptured like the frons. Pronotum deeply, coarsely reticulate-punctate, this becoming weaker near anterior border; the low weak median ridge is continuous throughout; on either side anteriorly are two short, broad, oblique, shallowly depressed areæ, which do not reach anterior margin, and are thickly, minutely punctate or shagreened within. Body of scutellum coarsely reticulate-punctate; scutellar furrow reticulate within, the lateral margins high and thin; spine with its point about 1 millimeter above apex of tegmina.

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[6] Characters given in the keys are not repeated in the descriptions, so that for complete diagnoses of the species, the two should be combined.

Male.—Length to end of abdomen, 3 millimeters; to end of tegmina, 4.5; to end of spine, 5.5.

Colors deeper than in the female, the pronotum almost piceous. The spine is more or less minutely dotted, and the lateral yellow marks on body of scutellum are abbreviated posteriorly.

This is a common species at Los Baños and on Mount Maquiling, both localities in Laguna Province, Luzon Island, Philippine Islands.

Machærota luzonensis Schmidt.

Machærota luzonensis SCHMIDT, Ent. Zeitg. Stettin 68 (1907) 189.

Female.—Length to end of abdomen, 4 millimeters; to ends of tegmina, 6; to end of spine, 7.

Color stramineous; spine, and scutellum caudad, pale reddish brown; legs yellowish. Frons yellowish, with eight horizontal piceous bands on either side, and with no median dark color except above; scutellum with an indistinct, median piceous stripe; posterior yellow border of body of scutellum broader below, the intramarginal, deeply depressed line piceous; the curved yellowish marks on sides of body of scutellum very indistinct; a few dark dots on borders of scutellar groove. Abdomen stramineous, ovipositor piceous.

Frons nearly smooth, indistinctly shagreened, the lower border, with clypeus, more coarsely sculptured; face almost entirely without appressed white pubescence. Pronotum coarsely reticulate-punctate except near anterior margin, but the reticulations are not sharp; the four slightly depressed oblique areæ near fore margin short, minutely roughened, and piceous; the median ridge sharp and high. Reticulate character of puncturation less evident on body of scutellum; spine strongly curved at base, its point a millimeter above the apex of tegmina.

In all of the Philippine material before me, there appear to be but two specimens that approximately fit the original description of Schmidt's species. These are from Davao, Mindanao Island, Philippine Islands.

Machærota ensifera Burm.

Machærota ensifera BURMEISTER, Handb. Ent. 2^1 (1835) 128.

The disposition of colors on pronotum in longitudinal stripes clearly marks this species in all of its various light and dark phases. The common form in Luzon is pale in color, but very dark-colored forms come from Palawan. The palest forms in my collection were taken in Imugan, Nueva Vizcaya Province, Luzon. The very broad, shining, black, median portion of face, broader above, is also characteristic in all color phases; in the Luzon forms this dark color is lacking on the lower frons and on clypeus, whereas in the dark Palawan forms it is broad throughout; only rudiments of horizontal, lateral, frontal stripes are present in any of the color phases. The four slightly depressed and finely sculptured oblique areæ near anterior border of pronotum are concolorous. The spine is scarcely curved where it joins body of scutellum, and its point is about 1.5 millimeters above apex of tegmina.

Abundant throughout the Philippine Islands.

Machærota fusca sp. nov.

Female.—Length to end of abdomen, 5 millimeters; to ends of tegmina, 7.25; to end of spine, 8.5.

Color stramineous to chocolate, to piceous, and strongly contrasted. Entire face black; vertex, pronotum, and scutellum chocolate; posterolateral areæ of pronotal disk stramineous; lateral angles of pronotum shining piceous; lateral areæ of vertex and short longitudinal stripes inclosing the ocelli posteriorly, stramineous; lateral yellow stripes on body of scutellum long, straight, more than two-thirds length of scutellar body and somewhat broader caudad; posterior border of scutellar body very narrowly and shortly yellowed; scutellar spine piceous. Pleuræ stramineous; venter piceous to brown; legs brown, femora stramineous at apex, fore and middle tibiæ stramineous at base, hind tibiæ stramineous on basal three-fourths. Abdomen stramineous above, with broad longitudinal lateral areæ brownish, the narrow venter brownish. Tegmina suffused with stramineous in the region of apical cells, where the veins are pale brown; the remainder of corium subhyaline with piceous veins.

Frons shining and nearly smooth except apically, laterally with subobsolete indications of a few horizontal lateral grooves; clypeus subrugose. Supra-antennal areæ of vertex foveate; frontal area of vertex depressed and with a delicate median carina, the true vertex rugose between the ocelli. Pronotum very coarsely reticulate-punctate except near fore margin, the reticula not sharp; the four finely sculptured depressed areæ near anterior margin very small; median ridge of pronotum weak, becoming obsolete posteriorly. Body of scutellum as coarsely sculptured as pronotum but more irregularly; scutellar furrow cross wrinkled within, and with borders but little raised; lower posterior angle of posterior border of scutellum unusually prominent. Spine strongly curved, its point 1 millimeter above the apex of tegmina.

Two females of this fine species were taken at Baguio, Mountain Province, Luzon, Philippine Islands.

Tribe SIGMASOMINI

Key to the genera.

a^1. Vertical projection of head very long and sword-shaped, the head thus longer than pronotum.. Sigmasoma Schmidt.

a^2. Vertical projection of head shortly acute, the head much shorter than pronotum .... Grypomachærota Schmidt.

Genus SIGMASOMA Schmidt

Sigmasoma bifalcata Schmidt.

Sigmasoma bifalcata SCHMIDT, Ent. Zeitg. Stettin 68 (1907) 181.

This remarkable insect was described from Java, but similar forms will probably be discovered in other parts of Malaya also.

Genus GRYPOMACHÆROTA Schmidt

Schmidt[7] describes but one species of this genus, *G. turbinata*, crediting it to Java, Sumatra, and Borneo. Due to the very imperfect figures presented by him, and his very insufficient description, it may be fairly questioned if all of his material belongs to one species. As shown hereinafter, some species which present an extraordinary similarity in color, are completely distinct structurally. Schmidt's failure to give full structural details makes it difficult to compare *G. turbinata* with the three species recorded herein from Borneo.

Key to the species.

a^1. Medial cell about five times as long as wide and far longer than stem vein; anterolateral and posterolateral margins of pronotum deeply incurved; length of frons above eyes greater than length below antennæ; posteroinferior angle of scutellum high above lower margin and minutely acute; color pale, darker punctured; face pale with dark crossbars (Plate II, figs. 8, 9, and 11; III, figs. 1, 4, 5, and 8). G. borneensis sp. nov.

a^2. Medial cell little more than twice as long as wide or less, and shorter than stem vein; anterolateral and posterolateral margins of pronotum not deeply incurved; length of frons above eyes less than length below antennæ; posteroinferior angle of scutellum in line with lower margin, and large, obtuse; color dark, head black.

  b^1. Scutellar spine not strongly decurved, its apex far above apex of tegmina.

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[7] Ent. Zeitg. Stettin 68 (1907) 183.

c^1. Scutellar spine but slightly longer than scutellum; height of head above eye equal to depth of eye.................. G. turbinata Schmidt.

c^2. Scutellar spine a half or nearly a half longer than scutellum; height of head above eye greater than depth of eye (Plate II, fig. 14; Plate III, figs. 2 and 6) .... G. tricolor sp. nov.

b^2. Scutellar spine strongly decurved, its apex near apex of tegmina; height of head above eye much less than depth of eye (Plate II, figs. 12 and 15; Plate III, figs. 3, 7, 9).............. G. breviceps sp. nov.

Grypomachærota borneensis sp. nov.

Female.—Length to end of abdomen, 5 millimeters; to ends of tegmina, 6.5; to end of spine, 7.

Stramineous; lower part of face, sternum, and venter piceous, the latter sometimes paler; frons piceous basally and apically, the middle two-fourths stramineous, and each side with eight narrow oblique piceous stripes; vertex dark brown except the stramineous superior cheek areæ, an area connecting ocelli, and the postocular areæ. Punctures of pronotum brown, this rendering conspicuous the stramineous reticula, median carina, and posterolateral borders. Scutellum and base and lower border of spine pale brown; lateral pale stripes on body of scutellum straight, oblique, passing backward and upward to beyond middle; median dorsal line on body of scutellum and entire upper portion of spine except at base (where it is piceous), stramineous; posterior margin of body of scutellum shortly and broadly yellowish and immediately above this piceous; the inferolateral border also narrowly yellowish. Tegmina slightly suffused with stramineous apically, the veins brown to piceous. Legs brown to piceous, apices of femora and nearly all of tibiæ stramineous.

Frons finely, transversely, rugosely wrinkled and shining, more coarsely sculptured below and on clypeus; frons evenly convex on lower half, but with a strong median carina on upper half, this reaching the upper angle of appendage, where the lateral margins are also sharply carinate. Vertex horizontally rugose, with a median carina which apically becomes sharply raised and double; lateral areæ of frontal portion of vertex concave. Pronotum coarsely reticulate-punctate except near anterior border, the reticula not sharp; four small, depressed, oblique, finely sculptured areæ near fore margin as in *Machærota*. Scutellum sculptured like pronotum, the furrow cross wrinkled and with the upper carina of spine scarcely entering it; spine at base with lateral disks sharply longitudinally depressed, its point 1.5 millimeters above apex of tegmina.

This is a common species at Sandakan, British North Borneo.

Grypomachærota tricolor sp. nov.

Female.—Length to end of abdomen, 4 millimeters; to end of tegmina, 5.5; to end of spine, 6.5.

Color black, with red-brown spine, short yellow lateral marks and narrow yellow posterior border of scutellum; tegmina with piceous veins, these apically smoky bordered.

Frons shining, minutely, irregularly, transversely rugose, a sharp median carina only on upper fourth where the lateral margins of appendage are very shortly carinate; clypeus coarsely rugose. Vertex strongly transversely wrinkled, with a short double median carina near apex; lateral areæ of frontal portion of vertex convexly rounded. Pronotum thickly, very coarsely reticulate-punctate, more weakly near fore margin, the reticula sharp; a weak median carina on apical third only; the four small depressed areæ near fore margin rather narrow and elongate. Scutellum sculptured like pronotum; the furrow short, broad apically, and very shallow; lateral surfaces of scutellum below furrow strongly depressed; the lateral depressions on base of spine very deep, foveate; apex of spine 2 millimeters above apex of tegmina.

This very distinct species occurs at Sandakan, British North Borneo.

Grypomachærota breviceps sp. nov.

Length to end of abdomen, 3.5 millimeters; to ends of tegmina and of spine, 5.

Black, with red-brown spine, short lateral yellow marks on scutellum and short yellowish posterior border; legs brownish; tegmina apically suffused with stramineous and with brownish veins; corium transparent, with piceous veins.

Frons shining, finely transversely rugose, entirely without median carina, and with upper lateral carinæ of appendage very weak; clypeus more coarsely sculptured. Vertex finely transversely wrinkled and without median carina. Pronotum and scutellum sculptured as in *G. tricolor;* sides of scutellum below furrow not strongly or broadly depressed, the posterior submarginal impressed line in this species being a long, broad fovea; base of spine laterally not deeply foveate; the very strongly curved spine approaches ends of tegmina within a half millimeter, and does not pass the ends of tegmina, thus differing from all other Malayan Machærotini.

Specimens of this species were collected on Penang Island, Wellesley Province, Straits Settlements. One might be inclined to place this with *G. tricolor* on color alone, but its structure is very different.

Tribe MAXUDEINI

Genus MAXUDEA Schmidt

From the viewpoint of species, the same difficulty pertains to this remarkably distinct genus as to *Grypomachærota*. The figure and the description given by Schmidt are exceedingly crude. His lateral view of the insect is a quartering one with the head turned slightly away, so that it is impossible to secure exact

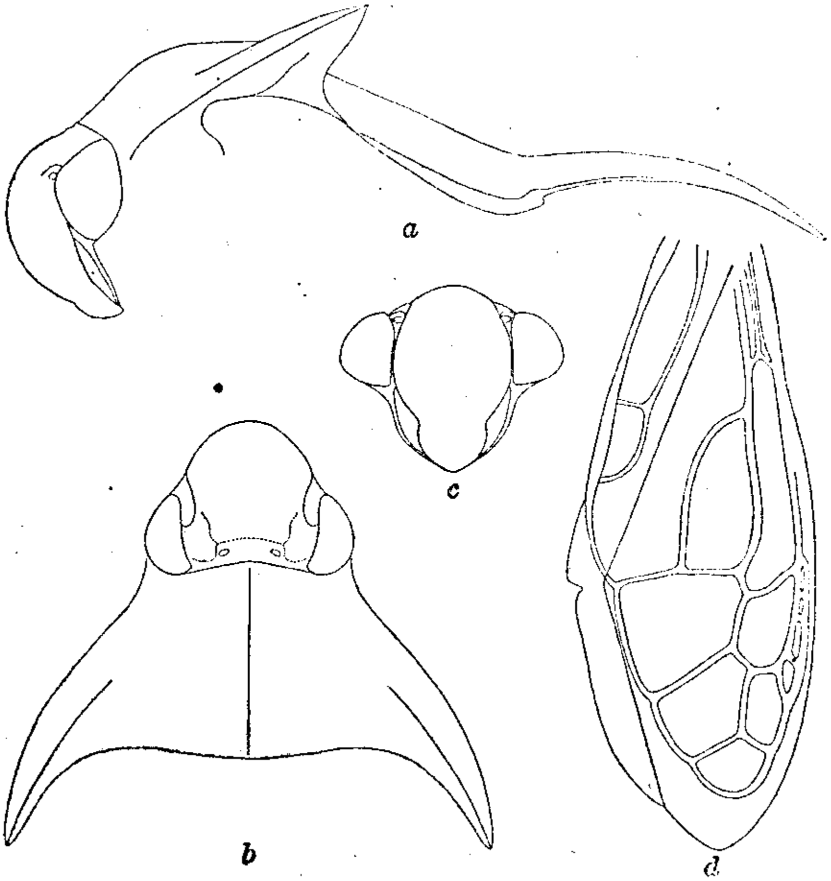

FIG. 1. *Maxudea schmidtii* sp. nov.; *a*, lateral view of head, pronotum, and scutellum; *b*, dorsal view of head and pronotum; *c*, face; *d*, tegmen.

proportions of scutellum or of pronotal laminæ. The structure at the base of the scutellar spine as shown for the Sumatran species described by Schmidt,[8] *Maxudea crassiventris*, is so entirely different from that of a species obtained from Penang, that it is necessary to maintain the latter as distinct, at least until better structural data as to *M. crassiventris* can be secured.

Key to the species.

*a*¹. Lower margin of scutellar spine, above posteroinferior angle, strongly concave..M. crassiventris Schmidt.

*a*². Lower margin of scutellar spine, above posteroinferior angle, straight. M. schmidtii sp. nov.

Maxudea schmidtii sp. nov.

Female.—Length to end of abdomen, 6.5 millimeters; to ends of tegmina, 7.5; to end of spine, 8; breadth from tip to tip of pronotal laminæ, 5.

Color largely piceous, the pronotal laminæ shining. Face stramineous, a broad median stripe and lower third of frons and clypeus black; lateral portions of frons with about eight dark horizontal lines; vertex stramineous with dark sutures; the frontal horizontal lines continued to ocellar (true frontal) transverse suture. Anterior portion of pronotum stramineous, with four dark spots; disk of pronotum piceous, laminæ black. Scutellar body stramineous with dark punctures, without yellow lateral marks or yellow posterior margin, the spine and inferolateral margins of scutellar body chocolate. Abdomen piceous, the segments with paler margins. Legs reddish brown, basal two-thirds of femora black. Tegmina suffused with stramineous, veins brownish, darker basally.

Frons shining, irregularly shallowly roughened, the horizontal lines being distinct shallow furrows; clypeus coarsely transversely wrinkled. Frontal portion of vertex with an acutely triangular median depression just in front of ocellar suture. Pronotum thickly, coarsely reticulated punctate except near anterior margin, the reticulæ and median carina sharp (stronger anteriorly); the four small depressed areæ near fore margin are irregularly subcircular; anteriorly and posteriorly the flattened laminæ are sharp margined; subparallel with anterior margin of lamina, and near to this margin, a sharp carina passes from disk of pronotum to tip of lamina, forming a sulcus between this and margin. Scutellar body sculptured like pronotum, the area of scutellar furrow slightly depressed, without raised margins, the strong reticula here greatly lengthened horizontally to form a series of horizontal carinæ; inferoposterior margin practically absent, the normal inferoposterior tooth of the other Machærotinæ adjoining the base of the spine. All pleuræ strongly rugose; seven tergites thickly, finely rugose-punctate; lower surface of femora bisulcate. Apex of spine 3 millimeters above ends of tegmina.

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[8] Ent. Zeitg. Stettin 68 (1907) 176.

A specimen of this unique insect was taken on Penang Island, Wellesley Province, Straits Settlements; this is the first record, belonging to the Asian mainland, for this genus.

ILLUSTRATIONS

PLATE I

FIG. 1. *Machærota notoceras* Schmidt, lateral view of head, pronotum, and scutellum.
2. *Machærota philippinensis* sp. nov., face.
3. *Machærota philippinensis* sp. nov., lateral view of head, pronotum, and scutellum.
4. *Machærota ensifera* Burm., lateral view of head, pronotum, and scutellum.
5. *Machærota ensifera* Burm., face.
6. *Machærota luzonensis* Schmidt, lateral view of head, pronotum, and scutellum.
7. *Machærota fusca* sp. nov., lateral view of head, pronotum, and scutellum.
8. *Machærota fusca* sp. nov., face.
9. *Machærota notoceras* Schmidt, dorsal view of head and pronotum.
10. *Machærota philippinensis* sp. nov., dorsal view of head and pronotum.
11. *Machærota ensifera* Burm., dorsal view of head and pronotum.
12. *Machærota luzonensis* Schmidt, dorsal view of head and pronotum.
13. *Machærota fusca* sp. nov., dorsal view of head and pronotum.
14. *Machærota ensifera* Burm., posterior legs, inner and outer view.

PLATE II

FIG. 1. *Machærota philippinensis* sp. nov., tegmen.
2. *Machærota fusca* sp. nov., hind wing.
3. *Machærota ensifera* Burm., tegmen.
4. *Machærota ensifera* Burm., hind wing.
5. *Machærota luzonensis* Schmidt, tegmen.
6. *Machærota luzonensis* Schmidt, tegmen, showing more normal venation than in fig. 3.
7. *Machærota fusca* sp. nov., tegmen.
8. *Grypomachærota borneensis* sp. nov., hind wing.
9. *Grypomachærota borneensis* sp. nov., tegmen.
10. *Machærota fusca* sp. nov., upper surface of scutellum, with furrow.
11. *Grypomachærota borneensis* sp. nov., upper surface of scutellum, with furrow.
12. *Grypomachærota breviceps* sp. nov., tegmen.
13. *Machærota luzonensis* Schmidt, upper surface of scutellum, with furrow.
14. *Grypomachærota tricolor* sp. nov., upper surface of scutellum, with furrow.
15. *Grypomachærota breviceps* sp. nov., upper surface of scutellum, with furrow.

PLATE III

FIG. 1. *Grypomachærota borneensis* sp. nov., lateral view of head, pronotum, and scutellum.

2. *Grypomachærota tricolor* sp. nov., lateral view of head, pronotum, and scutellum.
3. *Grypomachærota breviceps* sp. nov., lateral view of head, pronotum, and scutellum.
4. *Grypomachærota borneensis* sp. nov., as seen when dorsum of pronotum is horizontal.
5. *Grypomachærota borneensis* sp. nov., as seen when surface of vertex is nearly horizontal.
6. *Grypomachærota tricolor* sp. nov., as seen when surface of vertex is nearly horizontal.
7. *Grypomachærota breviceps* sp. nov., as seen when surface of vertex is nearly horizontal.
8. *Grypomachærota borneensis* sp. nov., face.
9. *Grypomachærota breviceps* sp. nov., face.

TEXT FIGURE

FIG. 1. *Maxudea schmidtii* sp. nov.; *a*, lateral view of head, pronotum, and scutellum; *b*, dorsal view of head and pronotum; *c*, face; *d*, tegmen.

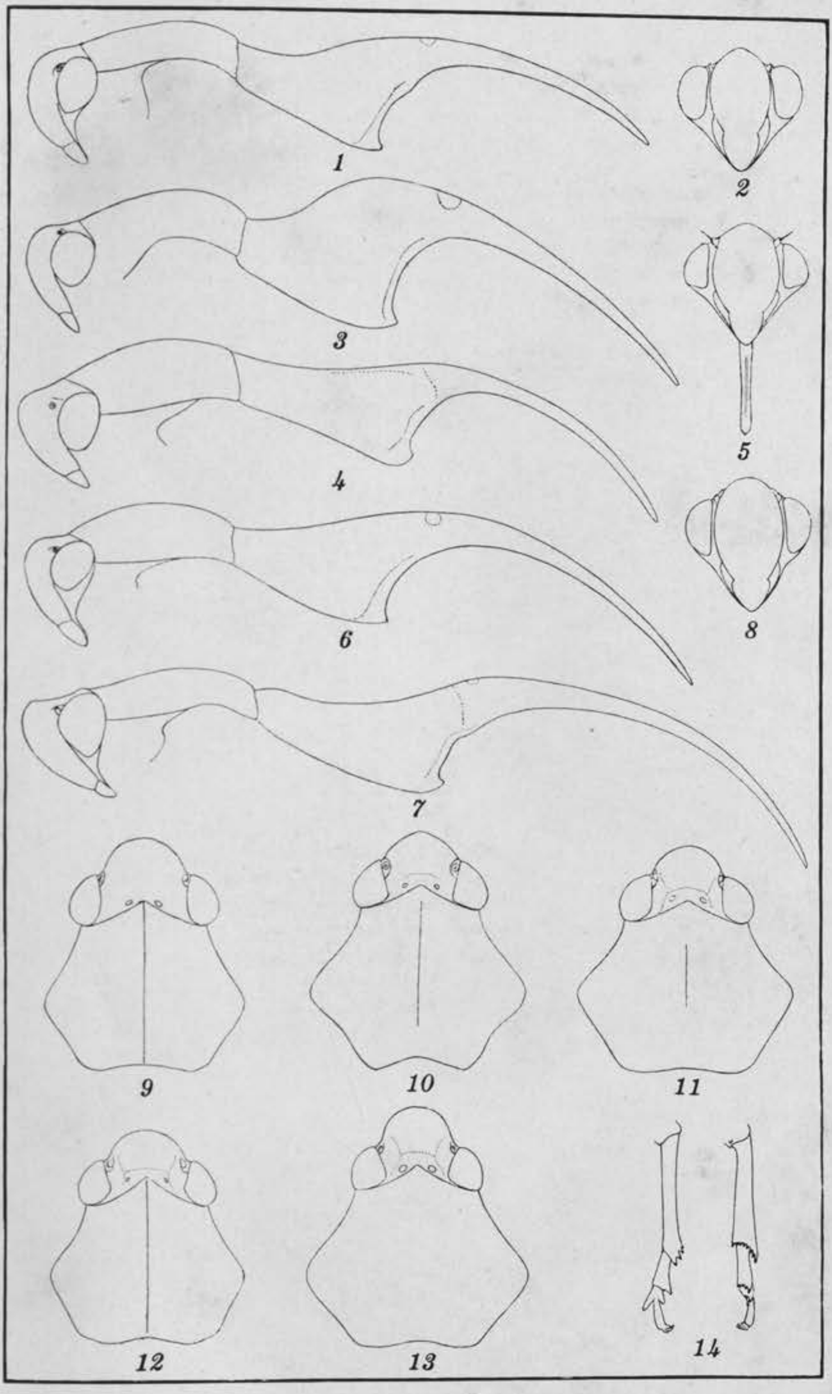

PLATE I. MALAYAN MACHÆROTINÆ.

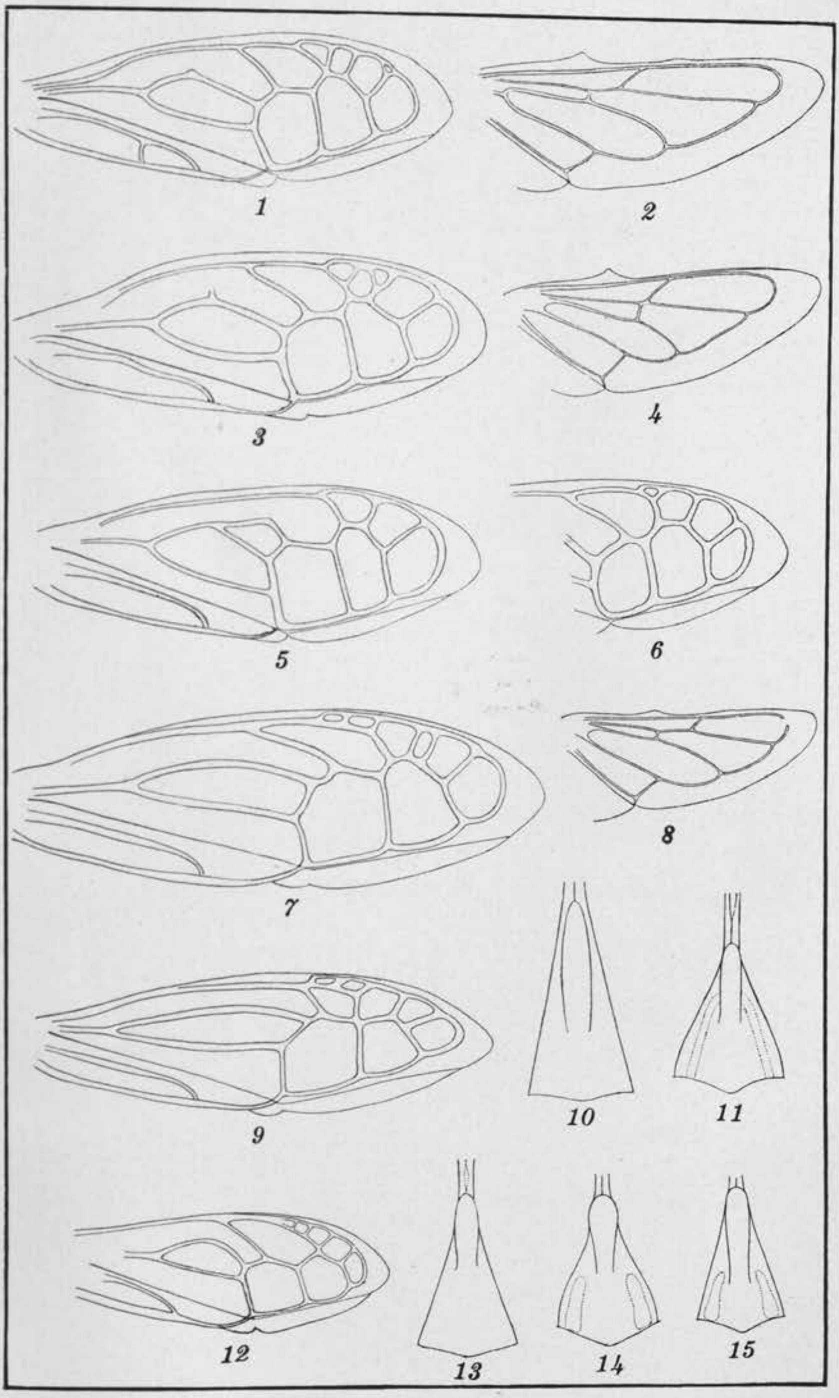

PLATE II. MALAYAN MACHÆROTINÆ.

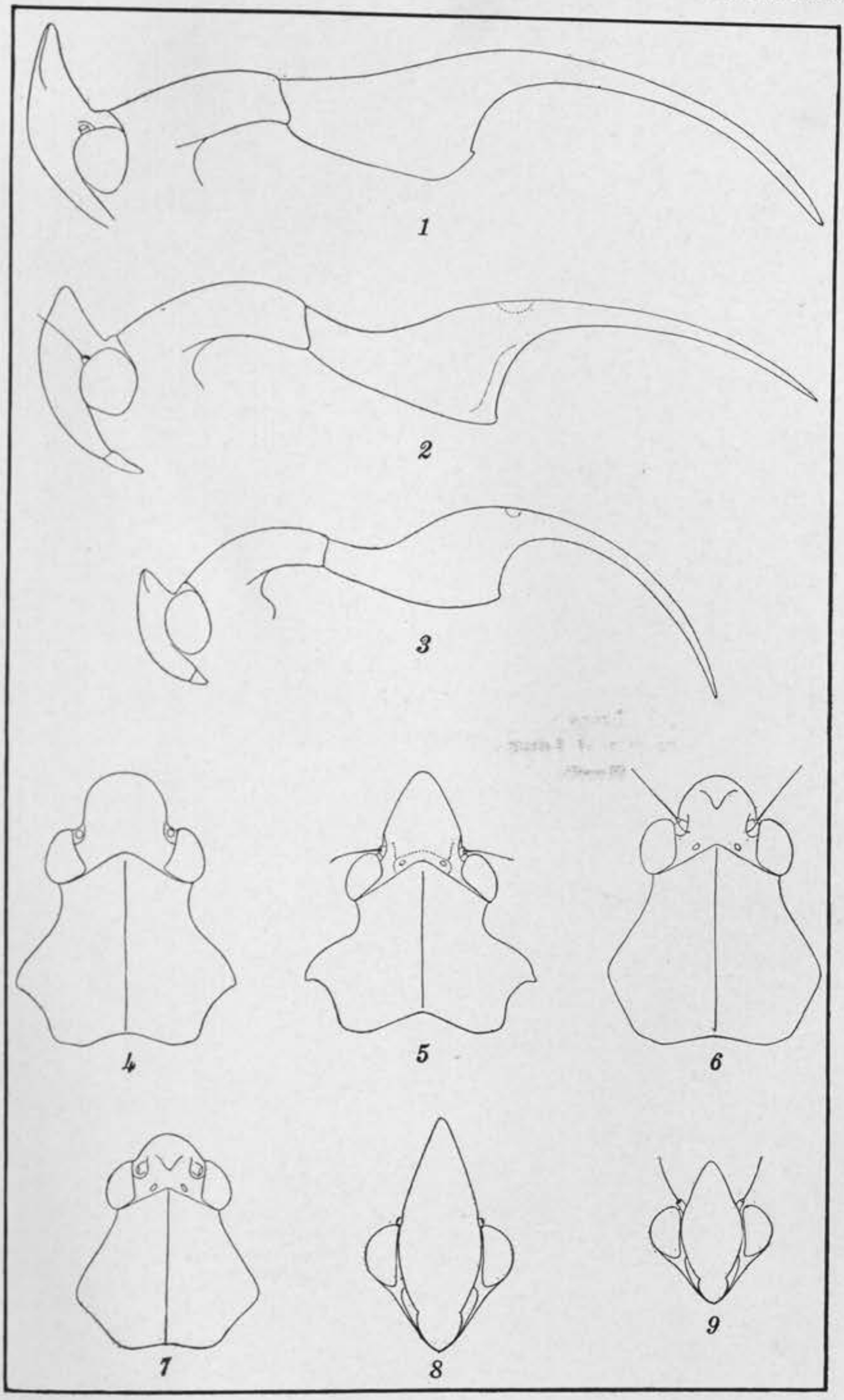

PLATE III. MALAYAN MACHÆROTINÆ.

HABITS OF TROPICAL CRUSTACEA: III

By R. P. Cowles

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ONE PLATE

HABITS AND REACTIONS OF HERMIT CRABS ASSOCIATED WITH SEA ANEMONES

The hermit crabs of the Philippine Islands form one of the most interesting groups of the tropical Crustacea on account of their peculiarities in structure and habits. Some of these hermits have an asymmetrical abdomen, of such a shape that the crab can insert it into the empty, spirally coiled shell of a mollusk and carry the shell about as a protection against enemies. Some hermit crabs of this kind spend practically all their lives in the sea among the rocks and the corals of rather deep water; some live close to the shore in shallow water; and others live far inland, visiting the sea only during the breeding period, at which time they usually exchange their old shells for new ones. Other hermit crabs have a straight, symmetrical or almost symmetrical abdomen; one of these, *Pylocheles miersii* Alcock and Anderson, lives in the sea and inhabits a joint of bamboo. Another kind, *Birgus latro* Linnæus, the coconut, or robber, crab, lives on land, carries no mollusk shell, and like the ordinary land hermits visits the sea only occasionally and possibly only at the breeding time.

While the peculiar anatomy and fitness for the environment of the hermit crabs are of interest, certain habits of these Crustacea are even more interesting. The hermit begins life in the sea; and, if it is of the ordinary kind that carries a spirally coiled mollusk shell, it seeks and enters one of a size suitable to its body. As the crab grows older it increases in size, thus necessitating a change now and then to a larger shell. This habit is not a new one to zoölogists, for undoubtedly it has been observed many times in many parts of the world. While, ordinarily, a hermit occupies a shell of the right size for its body, it sometimes happens that the shell is too small, so that a large part of the anterior portion of the body is exposed; or that the shell is so large that the crab can hardly be seen when it withdraws into the shell.

It seems probable, as Bouvier,[1] Thompson,[2] and Bohn[3] have held, that sometimes the change of shell is brought about spontaneously and at other times because the crab is uncomfortable.

An even more surprising habit which has been reported has to do with the association of hermit crabs with sea anemones. *Eupagurus bernhardus* Linnæus[4] carries on its shell the anemone *Sagartia parasitica* Gosse, while *Eupargus prideauxii* Leach,[5] *Pagurus arrosar* Herbst,[6] and *Paguristes oculatus* Fabricius[7] carry *Adamsia palliata* Bohadsch, *Adamsia rondeletii* Della Chiaje, and *Actinia equina* Linnæus, respectively. Recently[8] *Pagurus deformis* H. Milne-Edwards from the Loyalty Islands and British New Guinea has been described as bearing sea anemones on its shell, and a search through the literature shows that other hermit crabs in a similar condition have been reported; but I shall not list these since their habits do not seem to have been investigated.

The mere occurrence of sea anemones attached to the mollusk shells inhabited by hermit crabs does not close the list of the habits of these interesting animals. It has been reported[9] that when the hermit changes its shell it removes the sea anemones, placing them on the new shell, and that the sea anemones aid the hermit in this procedure.[10]

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[1] Bouvier, E. L., Observations sur les moeurs des pagures faites au laboratoire maritime de Saint-Vaast La-Houghe pendant le mois d'Aout 1891, *Bull. Soc. Philomath. Paris* 4 (1891–1892) 7.

[2] Thompson, M. T., The metamorphosis of the hermit crab, *Proc. Boston Soc. Nat. Hist.* 31 (1903) 193.

[3] Bohn, G., Les animaux marines littoraux, *Bull. l'Instit. Gén. Psychol.* 6 (1903) 625–626.

[4] Smith, Geoffrey, and Weldon, W. F. R., Cambridge Natural History, Crustacea and Arachnids 4 (1909) 172.

[5] Wortley, Stuart, On the habits of Pagurus Prideauxii and Adamsia palliata, *Ann. & Mag. Nat. Hist.* III 12 (1863) 388–390; Brehm's Thierleben 10 (1900) 41; Bronn's Thierreich (Ortmann) 5 (1901) 1254; Keller C., Das Leben des Meers (1895) 71; Calman, W. T., The Life of Crustacea (1911) 213; Agassiz, A., Instinct (?) in hermit crabs, *Ann. & Mag. Nat. Hist.* 17 (1875–1876) 100.

[6] Brunelli, G., Atti. Rend. R. Accad. Lincei. Roma 19 (1910) 77–82.

[7] Brunelli, G., loc. cit.

[8] Borradaille, L. A., On Stomatopoda and Macrura brought by Dr. Willey from the South Sea Islands, Willey Zoölogical Results pt. 4 (1900) 424.

[9] Wortley, Stuart, op. cit.; Gosse, P. H., On the transfer of Adamsia palliata from shell to shell, *The Zoologist* 18 (1859) 6582; Sluiter, C. P., Der Commensalismus zwischen Einsiedlerkrebsen und Actinien, *Kosmos* (1882) 391; Chevreux, M. E., Le Pagurus Prideauxii et ses Commensaur, *Compt. Rend. Assoc. Franc. Avancem. Sci.* (1884); Brehm's Thierleben 10 (1900) 41; Brunelli, G., op. cit.

Some zoölogical text books mention the fact that this transplanting of anemones has been reported; but the subject, if discussed, is generally treated, whether intentionally or not, as though there might be an element of doubt as to the occurrence of this habit. For the reasons mentioned, and because five of my coworkers and I have seen the transfer for the first time in the case of two species of hermits living in Philippine waters, I shall now record my observations.

Along the coast of Mindoro Island, in Port Galera Bay, there occur hermit crabs belonging to two species, *Pagurus deformis* and *Pagurus asper* de Haan, which inhabit mollusk shells of Dolidæ, Strombidæ, *Cassis*, etc. Both of these hermits almost invariably carry two different kinds of sea anemones on their shells; one, a large grayish brown form usually on the sides and another, much smaller, almost colorless form usually on the underside of the mollusk shell below the protruding head of the crab (Plate I). As many as eight of the large anemones and three or four of the smaller kind have been found on a single *Dolium* shell, but so great a number is rather unusual. While in the majority of cases the small anemones are attached on the underside of the mollusk shell below the head of the hermit and the large ones on the upper and lateral surface of the shell, occasionally specimens are found in which the order is reversed.

Either the anemones when in the larval condition attach themselves to the mollusk shell carried by the hermit, or they are placed there by the hermit when they are still very small. On one occasion a beautiful, clean shell which was not beach worn was collected containing a young specimen of *Pagurus deformis*. On the upper surface of this shell were three of the brown anemones, 2, 4, and 8 millimeters across, and just inside the mouth of the shell was one of the colorless species, 3 millimeters in breadth. The extreme smallness of the anemones in this case might indicate that they became attached to the mollusk shells in the larval stage, and this is borne out by the fact that in all our collections at Port Galera we have never found these anemones except on shells inhabited by hermits; but since the hermits show considerable facility in transferring the anemones, it may be that they detach very young ones from rocks in deep water unexplored by us. On one occasion three young hermits (*Pagurus deformis*) were brought in by collectors, and the shells that they occupied were devoid of anemones.

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[10] Eisig, H., Studien über tiergeographische und verwandte Erscheinungen, I. Zum Verständniss des Commensalismus der Einsiedlerkrebse (Paguriden) und Seeanemonen (Aktinen), *Das Ausland* (1882) 55, 681; Gosse, P. H., op. cit.

Wortley[11] has reported that the hermit crab when feeding may transfer pieces of food with its pincers to the sea anemone, but this behavior has not been observed by me nor, so far as I know, by other workers. In fact the accuracy of Wortley's observation has been doubted.[12] Hermits of both of the species of which I collected specimens at Port Galera usually frequent shallow water where there is a rather heavy growth of eel grass which harbors many small organisms. While it does not seem probable that the hermits feed the sea anemones, yet it must be admitted that the anemones are benefited by association with them in that the active, wandering life of the hermit crab presents an ever-changing feeding ground. The small colorless anemones attached at the shell's mouth and located directly under the head of the hermit crab undoubtedly obtain food from the hermit crab, but I have never seen them feeding (Plate I).

It need hardly be pointed out that the sea anemones afford protection for the hermit crab since, in addition to forming a covering which hides the latter, they discharge great numbers of stinging cells when disturbed by an enemy. The crab itself would undoubtedly be a choice morsel for large fishes such as sharks, but it has been pointed out that one mouthful of hermit crabs carrying sea anemones flavored with the piquant stinging cells would satisfy a fish for some time.

As soon as our collectors at Port Galera began to bring in hermits with anemones on their borrowed shells, I was anxious to see if the former would change their shells and transplant the anemones, as had been reported for a few other species in European waters. Accordingly I placed several individuals in an aquarium with a number of clean, empty *Dolium* shells. Nothing of interest happened for some time, but after about two hours one of the hermit crabs became active, took hold of an empty shell, withdrew its abdomen from the shell it was occupying, and inserted its abdomen, almost without examination, into the new shell. In order to have a better chance to observe what might happen, the old shell bearing the anemones and the hermit carrying its new, bare shell were placed in another aquarium. The hermit showed no interest in the anemones even after three-quarters of an hour, so after giving the hermit every encouragement such as placing the old shell near it, etc., I came to the conclusion that the species under consideration differs in this respect from the European species. But further observation with other specimens led me to believe that the removal of the hermit from one aquarium to another just after it had vacated the anemone-covered shell disturbed the hermit so much that the usually instinctive behavior in which the anemones are transferred to the new habitation was inhibited.

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[11] Wortley, S., op. cit.

[12] Eisig, H., op. cit.

I shall now describe my observations of a case in which the behavior of *Pagurus deformis* during its change of habitation may be called normal although inaccurate. In this case a hermit, in a shell carrying two large, grayish brown anemones on the upper surface and a small white one in the mouth of the shell, was placed near a *Dolium* shell somewhat larger than the one it was occupying. The hermit began to examine the new shell almost immediately; it put its pincers and some of its legs inside of the shell and remained in this position for a considerable length of time. Occasionally the pincers were moved about and were used apparently to examine the outside of the shell. Then, suddenly, the abdomen was inserted into the new shell, and the hermit without moving away grasped one of the large anemones, clawing, pinching, and pulling it. The anemone, instead of contracting as it would if disturbed by the observer, remained expanded even though the mauling it received was really very strenuous and although it was frequently jammed against the newly occupied shell. After these movements had continued for at least ten minutes the base of the anemone became loose in several places. Instead of completing its work at once, the hermit began to pinch and claw the other large anemone which withdrew its tentacles, soon however protruding them again. Then suddenly the hermit left the second one, and picked off the small white one which it applied at the mouth of the new shell almost directly under its own head, where the small anemone soon became firmly attached. Then the crab again attacked one of the large anemones, removed it easily, turned it round and round between its legs and pincers; and finally pushed the base against the side of the new shell. The anemone failed to become attached, slipped down onto the hermit's legs, stuck to them for a moment, dropped off, and finally attached itself to the glass bottom of the aquarium. Again the hermit crab seemed to lose interest in the anemone upon which it was working, and began tugging, pinching, and scratching the only one remaining attached to its old shell. After a long period of handling and some little prying up of the edges of the base of the anemone, during which time the tentacles contracted completely, the anemone suddenly slipped off, apparently of its own accord. The hermit then caught the anemone which had just slipped off, rolled it around and around for a few seconds and then, with the aid of the hind legs, applied the tentacle side against the shell. Again the anemone slipped off and was disregarded for a moment while the hermit picked up the other anemone. Still holding the latter it lifted up the one that had just slipped off and rolled them both around for some little time. Finally one became attached to the side of the shell by one edge of the base and was left to shift for itself. The other was passed up on the opposite side of the shell with the aid of the posterior legs of the hermit and soon both anemones became firmly attached with their tentacles beautifully expanded.

Strange as it may appear, the crab never seems to cause any injury, although the base of the anemone is very thin and when taken off by man is easily torn.

While the actions of this hermit crab were not nearly so accurate as those of some others I have observed, yet like all of them it showed a constant and hurried activity which seemed to indicate that some inherited nervous condition existed which was directing its actions. Furthermore, during the time in which this remarkable behavior was taking place the hermit crab, although at other times reacting quickly to movements outside of the aquarium, showed almost no reaction to the stimuli ordinarily produced by people passing or moving in front of the aquarium.

After the hermit had transferred all of the anemones from its old shell it began to work on the anemones of a small shell inhabited by another hermit crab. The latter immediately withdrew into its shell but left the large pincer exposed and open, so that one of the legs of the intruder slipped into the trap and was caught. The hermit, thus held fast, discontinued its attack for a time; in fact, until the captor loosened its hold and allowed the leg to be withdrawn. Instead of leaving, however, the attacking hermit renewed the scratching, pinching, and pulling until it was caught again by the leg. The intruder was held in this way for about a half hour during which it was inactive; but as soon as the leg was released the mauling of the anemones began again. These activities were repeated several times, but as long as I watched the two hermit crabs no anemone was removed.

I have observed other hermit crabs of the species *Pagurus deformis* which were even more inaccurate in their actions than the one we have just considered. In one case a hermit changed to an empty shell, worked on the anemones of the old shell for a few moments, and then took up its habitation again in the old shell. Soon, however, it inserted its abdomen again into the new shell and after about an hour's work succeeded in loosening an anemone. This it lifted upside down to the upper surface in such a manner that it became attached to the apex of the shell merely by one edge of the base where it hung with the tentacles hanging downward. Soon, however, partly as the result of the hermit moving about and turning its shell, the anemone became firmly attached in its normal position with the tentacles directed upward. About an hour later the hermit succeeded in removing another large anemone from its old shell, but instead of setting it on top the hermit placed it in the mouth of the new shell where the smaller species of anemone is usually put. The transfer of the latter (there were two of these) was not seen. Observations on this hermit were discontinued until the next morning when I found that both of the large anemones were in their usual positions on the back of the new shell, the one formerly placed at the mouth either having been transplanted by the hermit during the night or having moved of its own accord to the outside of the shell. One of the small anemones had been removed from the old habitation and apparently an attempt had been made to attach it at the mouth of the shell; but the transfer had been inaccurate, so that the anemone had become attached at the base of the walking legs of the crab near the mouth. The other small anemone was still attached to the old shell.

In the case of the species of hermit crab *Pagurus asper* the transfer of anemones from one shell to another was accomplished in practically the same manner as in the case of *Pagurus deformis*, except that the movements were slower.

My observations on the active and speedy shore crab *Ocypoda arenaria* Catesby [13] and the experiments of Yerkes and Huggins [14] with the crayfish show that, in the case of the former, past experiences leave an impress at least on the nervous system, and that the crayfish is able to solve very simple problems, such as finding its way out of a very simple labyrinth with greater and greater accuracy as the number of trials is increased. Such a "mind" is probably possessed by the hermit crab, but it would require a great stretch of imagination to believe that the hermit crab, if it really feeds the anemone, does so with the knowledge that it is caring for an animal which protects it from enemies; or that, when the hermit crab removes the sea anemones from a shell which it has left and plants them on a new home, it knows that they will be of future use; or that, when the anemone allows itself to be pinched and pulled and pried away from a shell by a hermit, it knows that it is in the hands of a friend. We cannot believe that this lowly crustacean, during its lifetime, has learned by experience that its care of the sea anemone is advantageous, although we know that crabs in general do profit by experience. Yet, assuming that the remarkable behavior of the hermit is due to instinct—that is, to an "inherited combination of reflexes" which have been so brought together by the nervous system that the behavior has become fixed and adaptive in the species—it is extremely difficult to conceive how it has acquired these habits.

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[13] Cowles, R. P., Habits, reactions, and associations in Ocypoda arenaria, *Papers Tortugas Lab. Carnegie Inst. Washington* 2 (1908) 34.

[14] Yerkes, R. M., and Huggins, G. E., Habit formation in the crawfish Cambarus affinis, *Harvard Psychological Studies* 1 (1903) 565.

ILLUSTRATIONS

PLATE I

FIG. 1. A hermit crab, *Pagurus deformis* Edw., carrying large and small sea anemones on its shell. Drawn from a preserved specimen from Port Galera, Mindoro. Slightly less than natural size.

2. Hermit crabs, showing large and small sea anemones attached to the shells. From a photograph of living specimens.

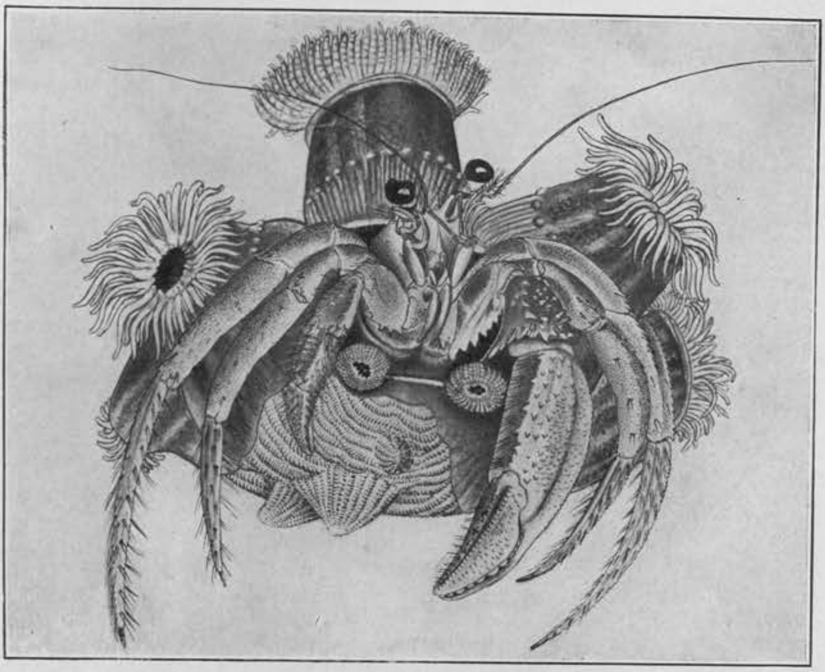

Fig. 1. A hermit crab, carrying large and small sea anemones on its shell.

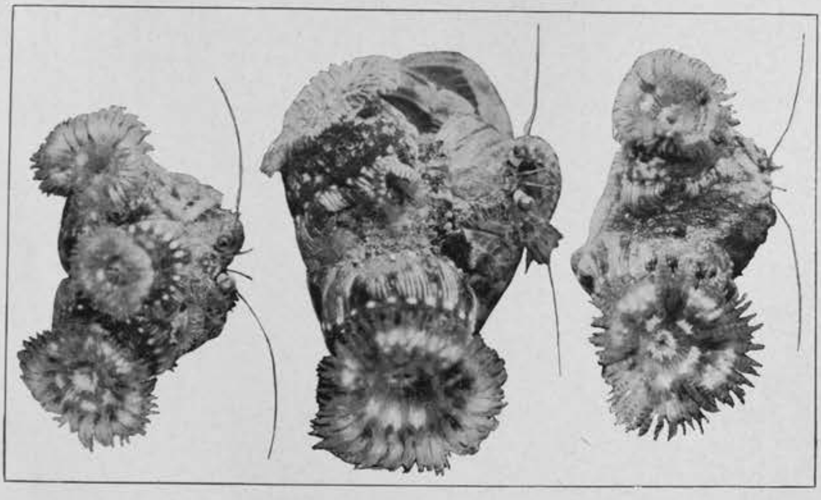

Fig. 2. Hermit crabs with sea anemones attached to the shells.

PLATE I.

MILK PRODUCED IN SOUTHERN CHINA [1]

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ONE PLATE

Through investigations begun in November, 1916, some interesting data have been secured in regard to the milking qualities of native and European cattle in southern China.

Three classes of milk animals have been studied: European cattle, the native water buffalo (known in the Philippine Islands as carabao), and the native, humped cattle. The work has been done chiefly in the vicinities of Canton and Hongkong, the only regions in Kwangtung (which is the southernmost province in China) where dairying has as yet developed into an industry of any extent.

European cows, or foreign cows as the Chinese call them, are the most popular for dairy purposes. In the dairies of Canton and Hongkong, which utilize approximately 1,600 cows, about 1,200 are European. The European cows have been imported from Australia, America, and England, or are the offspring of such imported cows. In the various dairies may be found Shorthorns, Holsteins, Ayrshires, Guernseys, Jerseys, and crosses among these breeds and with the native, humped cows. There are a few pure-bred cows. The Shorthorns, which are the commonest, are chiefly of the white, hornless variety that have been imported from Australia.

European cows are never allowed to graze because of the presence everywhere in the grass of the fever tick. They readily contract fever when exposed to it, and the disease usually proves fatal. However, European cattle born in southern China readily become immune to the fever, as they do in Texas where fever is common. In spite of the greater labor and risk experienced in keeping European cows, they are preferred to the native cows because of the larger amount of milk given and their efficiency, as compared with native cattle, in converting feed into milk.

A good description of the water buffalo (*Bubalus bubalis* Lyd.), of southern China, is given by Bailey.[2] The buffalo is principally used for draft purposes. Old animals are slaughtered for beef. In Canton, Hongkong, and other cities of southern China an increasing number is kept for the rich milk produced. There are no special breeds of dairy buffalo in southern China as there are in India. Buffaloes kept for milk are usually mature cows that have been used as draft animals for some time. During the period a cow is milked she is not required to work in that capacity. When milked, and fed grain and good grass, the cows have a long lactation period. It is not uncommon for them to give milk for from eight to twelve or more months. While the amount of milk is very low—usually from 3 to 15 pounds a day (about 1.4 to 6.8 kilograms), with an average of about 4.5 pounds (about 2 kilograms) a day for the lactation period—it is very rich in fat, containing from three to four times as much fat as European cows' milk.

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[1] Some of the data contained in this paper have been published in bulletin 17, Canton Christian College, Canton, China.

Œstruation in the female buffalo does not occur, as a rule, until the heifer is two years old. It occurs one month after parturition, and reoccurs regularly every twenty-eight to thirty days until the animal again becomes pregnant.

I have secured definite records on the exact length of the gestation period with only two cows; in one case it was three hundred ten days, and in the other, three hundred fourteen.

In order to secure a long lactation period as well as the maximum amount of milk, buffalo cows kept for milk are usually not bred until three or four months after freshening. The cows are considered profitable for dairy purposes until they are about 15 years old.

The Chinese in South China call the native cow *wong ngan*, "yellow cow." This bovine is a variety of the humped species of cattle (*Bos indicus*) common in the Orient. The hump is much less pronounced than it is in most breeds of Indian cattle. In the males the hump is usually 6 to 8 inches high above the shoulders. It is much smaller in the females than in the males. The dewlap is large, but is not developed to the degree common in Indian cattle. In color, these native yellow cattle are similar to the Jerseys. They vary from yellow-red to brown-black. Many are brindle. There are no white, and very few spotted, individuals. The tongue, nostrils, and teats are black. The cream-colored ring above the nostrils in the Jersey is also a characteristic of these cows. Males weigh from 800 to 1,000 pounds (about 362 to 454 kilograms). Mature females weigh from 600 to 800 pounds (about 272 to 362 kilograms). Their milk is considerably richer in fat than is that of any European breed, though not so rich as is the buffalo milk. The amount of milk given is usually about the same as that given by the buffalo cows, or a little less. They have a full, deep quarter and a deep layer of meat on the loin and back. They are used chiefly for draft and beef purposes. They are gentle, and much easier to handle than are the buffaloes. Very few are milked.

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[2] Cyclopedia of American Agriculture 3 (1908–09) 292.

MILK ANALYSES

In making the fat analyses of milk a Babcock fat-testing outfit was used. The proteins were determined by the Kjeldahl method described by Hawk.[3] The total solids were determined by evaporating a weighed sample of milk on a steam bath until the weight became constant. The ash was determined by heating the evaporated total solids over a gas flame until the weight became constant. The amount of sugar was found by subtracting the sum of the fat, ash, and proteids from the total solids. The percentage of each was found by dividing the weight of the final product by the weight of the sample of milk analyzed.

TABLE I.—*Showing analyses of Canton buffaloes' milk, European cows' milk in Canton, European cows' milk in America, and native, yellow cows' milk.*

[Numbers give percentages.]

Constituent.	Canton buffalo.	European cow, Canton.	European cow, America.	Yellow cow.
Fat	12.60	3.80	3.69	8.00
Proteins	6.04	3.23	3.53	
Sugar	3.70	5.96	4.88	
Ash	0.86	0.82	0.73	
Water	76.80	86.20	87.17	
Total solids	23.20	13.90	12.25	

All the samples of milk analyzed were taken by me directly from the barn as each cow was milked; not from bottled milk that is sold to the public and is frequently diluted with water.

The analyses show that European cows' milk is practically the same as when produced in the countries from which the cows have come. With more analyses the slight differences in some of the constituents will probably prove to be still less. Sixty duplicate analyses of fat, or one hundred twenty in all, from the milk of twelve cows, extending over a period of eighteen months, were made. Ten analyses were made for each of the remaining constituents.

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[3] Practical Physiological Chemistry. P. Blakiston's Son & Co., Philadelphia (1916) 483.

The analyses of buffalo milk included four hundred duplicate analyses for fat in a herd of fifty buffalo cows kept in the Canton Christian College dairy, including both individual and herd tests, and herd tests of five dairies in Canton. Compound analyses of both morning and afternoon milk were also made. The average was found to be 12.60 per cent fat. The lowest test was 9.80 per cent. The lowest average for a lactation period of all the cows was 9.65 per cent. The highest average was 15.60 per cent. The percentages of constituents in the buffalo milk other than fat represent averages of ten analyses. The protein varied from 5.60 to 6.10, with an average of 6.04 per cent. Sugar was low, varying from 3.51 to 3.75, with an average of 3.70 per cent. The average for ash was 0.86, varying from 0.71 to 0.99 per cent. The total solids averaged 23.20, varying from 21.00 to 25.20 per cent.

Tables II and III give the analyses of milk for fat, and Tables IV to XVII the production records of buffalo cows for which we have records extending over a period of several months, or for entire lactation periods. The analyses for butter fat were made twice a month. The milk for twenty-four hours was weighed twice a month. The average of the two analyses was taken as the average for the month, and the average amount of milk at the two weighings was taken as the average daily production for the month. The cows were all in the Canton

TABLE II.—*Complete analyses of buffalo milk.*

[The samples analyzed were composite samples taken from twelve cows in the college dairy in November, 1917. The milking in the morning was begun at 4 o'clock, and in the afternoon, at 2 o'clock. Numbers give percentages.]

Sample No.	Time.	Fat.	Ash.	Protein.	Sugar.	Total solids.	Water.
1	a. m.	11.00	0.94	6.04	4.00	22.98	77.02
2	p. m	12.80	0.90	6.10	3.57	23.37	76.63
3	do	13.00	0.71	5.71	3.32	23.02	76.98
4	do	13.63	0.74	5.94	3.57	22.88	77.08
5	do	12.10	0.90	6.14	3.83	22.87	77.04
6	do	14.00	0.92	6.42	3.87	25.21	74.79
7	a. m.	11.50	0.95	5.80	3.70	22.95	77.05
8	do	12.00	0.94	6.00	3.60	22.54	77.45
9	do	12.34	1.04	6.28	3.71	23.37	76.63
10	do	12.20	0.77	5.90	4.23	23.02	76.98
Averages		12.46	0.88	6.04	3.70	23.08	76.92

Christian College dairy at the time that the tests and the records were made.

The grain fed consisted of a ration made up of 2 pounds wheat bran and 1 pound rice chop. Each of the cows was fed about 1 pound of this mixed feed a day for each pound of milk given. The chop was fed cooked, and the bran was added to the rice after the rice was cooked. This feed was fed separately

TABLE III.—*Complete analyses of European cows' milk. Analyses made during January and February, 1917.*

[Numbers give percentages.]

Sample No.[a]	Fat.	Ash.	Protein.	Sugar.	Total solids.	Water.
1	3.20	0.745	3.18	6.47	13.70	86.30
2	3.50	0.840	3.20	5.28	13.82	86.18
3	4.50	0.736	3.24	5.18	14.65	85.35
4	4.60	0.900	4.10	5.20	13.80	86.20
5	3.80	0.780	3.25	5.54	13.37	86.63
6	4.44	0.800	3.10	5.60	13.94	86.06
7	3.50	0.880	3.80	6.00	13.97	86.03
8	4.10	0.888	3.40	5.63	14.12	85.88
9	5.20	0.740	3.20	5.30	14.44	85.56
10	4.00	0.800	3.05	6.10	13.95	86.05
Averages	3.96	0.820	3.23	5.96	13.90	86.21

[a] Samples 1 and 2 are of milk from the Hongkong Dairy Farm Co., in Victoria, Hongkong. The samples are from bottled milk from a herd of from 500 to 700 European cows, most of which are Holsteins. Samples 3, 4, 5, 6, and 7 are from the mixed milk of the Sinkee Dairy, in Canton. In this dairy 90 to 100 foreign cows are kept, Guernseys and Shorthorns predominating. Samples 8, 9, and 10 are from the mixed milk of four cows in the Canton Christian College dairy. These four cows are of mixed breeding with Shorthorn blood predominating.

TABLE IV.—*Milk produced by buffalo cow 1. Average fat for six months, 12.23 per cent.*

[Freshened in August, 1916. Lactation period ended June 30, 1917. Records began January 1, 1917.]

Month.	Morning.		Afternoon.		For 24 hours.		Average fat.	Total for month.	
	Milk.	Fat.	Milk.	Fat.	Milk.	Fat.		Milk.	Fat.
	lbs.	*P. ct.*	*lbs.*	*P. ct.*	*lbs.*	*lbs.*	*P. ct.*	*lbs.*	*lbs.*
January	2.20	10.24	2.00	12.00	4.20	0.484	11.5	130.2	14.97
February	2.00	10.20	2.30	12.90	4.30	0.503	11.9	120.4	12.82
March	1.50	11.20	1.30	13.80	2.80	0.346	13.3	84.0	11.21
April	2.00	12.50	1.50	13.50	3.50	0.450	13.0	105.0	13.65
May	1.70	12.50	1.20	14.50	2.90	0.386	12.6	89.9	11.95
June	0.50	12.00	0.25	14.00	0.75	0.100	13.3	22.50	2.99
Totals for six months	------	------	------	------	------	------	------	552.0	67.59

to each cow twice a day. About 0.75 ounce of salt was mixed with the grain at each feeding. About 40 pounds of water were added to the grain at each feeding, making a very wet feed, the cows drinking it. This is the usual method of feeding grain to cattle in southern China. The cows were fed four times a day all they could consume of a mixture of green grasses, cut along the canal dikes or from the college campus. The amount of grass eaten daily by each cow varied from 40 to 60 pounds.

The milk of the native yellow cow is rich in fat, averaging about 8 per cent. No analysis has been made of this milk for constituents other than fat.

TABLE V.—*Milk produced by buffalo cow 2. Average fat for lactation period, 11.80 per cent.*

[Freshened January 28, 1917. Lactation period ended September 30, 1917.]

Month.	Morning.		Afternoon.		For 24 hours.		Average fat.	Total for month.	
	Milk.	Fat.	Milk.	Fat.	Milk.	Fat.		Milk.	Fat.
	lbs.	*P. ct.*	*lbs.*	*P. ct.*	*lbs.*	*lbs.*	*P. ct.*	*lbs.*	*lbs.*
February	2.7	8.8	2.3	13.8	5.0	0.541	10.9	140	15.26
March	2.7	9.0	1.1	13.0	4.0	0.474	10.1	124	13.64
April	3.3	10.0	2.8	15.1	6.1	0.753	12.2	183	22.57
May	2.0	9.0	1.9	13.1	4.1	0.447	10.8	127	13.72
June	2.75	9.00	2.25	13.5	5.0	0.451	9.0	150	13.50
July	2.5	10.5	2.2	12.6	4.7	0.539	11.5	148	16.75
August	2.0	11.0	1.5	14.2	3.5	0.432	12.2	109	13.45
September	1.8	11.6	1.2	14.4	3.0	0.372	12.4	90	11.16
Totals for eight months								1,071	120.05

TABLE VI.—*Milk produced by buffalo cow 3. Average fat for six months, 12.95 per cent.*

[Freshened October 20, 1916. Lactation period ended June 28, 1917. Records began January 1, 1917.]

Month.	Morning.		Afternoon.		For 24 hours.		Average fat.	Total for month.	
	Milk.	Fat.	Milk.	Fat.	Milk.	Fat.		Milk.	Fat.
	lbs.	*P. ct.*	*lbs.*	*P. ct.*	*lbs.*	*lbs.*	*P. ct.*	*lbs.*	*lbs.*
January	2.0	11.8	2.7	13.8	4.7	0.606	12.8	145.7	17.45
February	2.3	12.0	1.5	14.0	3.8	0.486	12.6	106.4	13.40
March	2.3	13.2	1.1	15.4	3.4	0.473	14.0	105.4	14.76
April	2.1	12.2	1.2	14.2	3.3	0.436	13.3	99.0	13.16
May	1.9	13.5	1.3	14.5	3.2	0.444	13.90	99.2	13.79
June	1.9	12.2	0.75	13.0	2.65	0.322	12.2	79.5	9.70
Totals for six months								635.2	82.26

In all regions where buffalo milk has been analyzed it has been found to contain a great deal more fat than does European cows' milk. However, in no region from which the analysis of milk has been reported does the buffalo milk contain as much fat as in southern China.

A breed of buffaloes known as the Delhi buffalo (known in the Philippine Islands as the ram's horn buffalo) from North Central India has been introduced into Hongkong. This is an excellent breed for dairy purposes, because of the amount and quality of milk given. According to Hongkong authorities the milk contains about the same amount of fat as does the native Chinese buffalo milk. One of these Delhi buffalo dairies at

TABLE VII.—*Milk produced by buffalo cow 4. Average fat for lactation period, 12.63 per cent.*

[Freshened January 2, 1917. Lactation period ended November 30, 1917.]

Month.	Morning.		Afternoon.		For 24 hours.		Average fat.	Total for month.	
	Milk.	Fat.	Milk.	Fat.	Milk.	Fat.		Milk.	Fat.
	lbs.	*P. ct.*	*lbs.*	*P. ct.*	*lbs.*	*lbs.*	*P. ct.*	*lbs.*	*lbs.*
January	2.4	11.2	2.2	14.2	4.6	0.581	12.6	133.4	16.80
February	2.8	12.0	2.0	15.6	4.8	0.648	13.3	134.4	17.87
March	3.2	11.8	2.4	14.1	5.6	0.715	12.8	173.6	22.22
April	2.5	11.0	2.1	14.5	4.6	0.579	12.6	138.0	17.39
May	2.4	11.4	2.0	14.8	4.4	0.570	12.4	132.0	16.38
June	2.2	11.0	1.8	15.0	4.0	0.514	12.8	120.0	15.16
July	2.2	12.5	1.3	16.0	3.5	0.438	13.8	108.0	14.90
August	1.9	10.1	1.1	13.0	3.0	0.335	11.0	93.0	10.23
September	2.3	11.0	1.5	14.8	3.8	0.475	12.5	114.0	14.25
October	2.6	11.5	1.2	15.3	3.8	0.483	12.4	114.0	14.11
November	1.5	10.2	1.0	12.5	2.4	0.278	11.1	72.0	8.00
Totals for eleven months								1,332.4	167.31

TABLE VIII.—*Milk produced by buffalo cow 5. Average fat for five months, 13.12 per cent.*

[Freshened August 10, 1916. Lactation period ended June 30, 1917. Records began January, 1917.]

Month.	Morning.		Afternoon.		For 24 hours.		Average fat.	Total for month.	
	Milk.	Fat.	Milk.	Fat.	Milk.	Fat.		Milk.	Fat.
	lbs.	*P. ct.*	*lbs.*	*P. ct.*	*lbs.*	*lbs.*	*P. ct.*	*lbs.*	*lbs.*
January	2.7	11.25	2.0	12.70	4.7	0.557	11.87	145.7	17.29
February	2.3	12.50	2.0	13.80	4.3	0.494	11.54	120.0	13.68
March	2.3	13.50	1.1	15.50	3.4	0.481	14.15	105.4	15.31
April	2.0	14.00	1.5	15.00	3.5	0.505	14.40	105.0	15.12
May	1.9	13.90	1.3	15.10	3.2	0.460	14.30	99.2	14.18
Totals for five months								575.3	75.58

TABLE IX.—*Milk produced by buffalo cow 6. Average fat for six months, 12.34 per cent.*

[Freshened August 2, 1916. Lactation period ended June 24, 1917. Records began January 1, 1917.]

Month.	Morning.		Afternoon.		For 24 hours.		Average fat.	Total for month.	
	Milk.	Fat.	Milk.	Fat.	Milk.	Fat.		Milk.	Fat.
	lbs.	*P. ct.*	*lbs.*	*P. ct.*	*lbs.*	*lbs.*	*P. ct.*	*lbs.*	*lbs.*
January	2.2	9.0	1.7	12.9	3.9	0.414	10.6	120.9	12.81
February	2.4	10.0	1.7	14.1	4.1	0.480	11.7	114.8	13.41
March	1.9	13.0	1.4	16.3	3.3	0.435	13.2	102.1	13.47
April	2.0	10.5	1.4	13.9	3.4	0.425	11.9	102.0	12.14
May	1.2	12.00	0.9	12.5	2.1	0.268	12.88	63.1	8.42
June	1.2	10.2	1.2	12.5	2.4	0.282	11.69	72.0	8.41
Totals for six months								574.9	68.66

TABLE X.—*Milk produced by buffalo cow 7. Average fat for five months, 13.82 per cent.*

[Freshened July 4, 1916. Lactation period ended May 31, 1917. Records began January 1, 1917.]

Month.	Morning.		Afternoon.		For 24 hours.		Average fat.	Total for month.	
	Milk.	Fat.	Milk.	Fat.	Milk.	Fat.		Milk.	Fat.
	lbs.	*P. ct.*	*lbs.*	*P. ct.*	*lbs.*	*lbs.*	*P. ct.*	*lbs.*	*lbs.*
January	2.2	12.2	1.2	13.6	3.4	0.432	12.84	92.0	11.81
February	1.7	12.0	1.5	15.2	3.2	0.432	13.2	89.6	11.83
March	1.3	12.0	2.0	15.3	3.2	0.464	14.1	118.0	16.64
April	1.8	13.1	2.1	16.0	3.9	0.441	14.7	107.0	15.73
May	0.6	16.0			0.6	0.096	16.0	18.6	2.87
Totals for five months								425.2	58.88

TABLE XI.—*Milk produced by buffalo cow 8. Average butter fat for five months, 15.48 per cent.*

[Freshened May 2, 1916. Lactation period ended May 31, 1917. Records began January 1, 1917.]

Month.	Morning.		Afternoon.		For 24 hours.		Average fat.	Total for month.	
	Milk.	Fat.	Milk.	Fat.	Milk.	Fat.		Milk.	Fat.
	lbs.	*P. ct.*	*lbs.*	*P. ct.*	*lbs.*	*lbs.*	*P. ct.*	*lbs.*	*lbs.*
January	1.5	14.0	1.7	17.2	3.2	0.481	15.0	99.2	14.8
February	1.8	14.6	1.0	17.4	2.8	0.437	15.6	76.4	11.92
March	1.4	14.4	0.8	17.6	2.2	0.333	15.1	68.2	10.30
April	1.1	15.0	0.7	16.7	1.8	0.227	15.4	54.0	8.32
May	1.1	16.5	1.0	17.6	2.1	0.347	16.5	65.1	10.74
Totals for five months								362.9	56.08

Kowloon, Hongkong, had thirty cows that were giving from 10 to 20 pounds of milk a day on dry rice straw and very little rice and bran, when visited by me in January, 1919. When given succulent feed they give from 30 to 50 pounds of milk a day. These cows have a lactation period of from eight to twelve months. How well the flow of milk is kept up throughout the lactation period is not known.

Buffalo milk is pure white, with absolutely no tint of yellow. Cream and butter made from it are rather oily and have but a faint tint of yellow. By mixing European cows' cream with the buffalo cream and using vegetable butter color the color and the texture can be greatly improved.

TABLE XII.—*Milk produced by buffalo cow 51. Average fat for lactation period, 9.65 per cent.*

[Freshened July 4, 1918. Lactation period ended May 30, 1919. Records began immediately after freshening.]

Month.	Morning.		Afternoon.		For 24 hours.		Average fat.	Total for month.	
	Milk.	Fat.	Milk.	Fat.	Milk.	Fat.		Milk.	Fat.
	lbs.	*P. ct.*	*lbs.*	*P. ct.*	*lbs.*	*lbs.*	*P. ct.*	*lbs.*	*lbs.*
July	6.2	8.5	5.0	9.5	11.2	1.002	8.9	202.4	22.67
August	6.8	8.5	4.8	10.0	11.6	1.058	9.12	359.0	32.77
September	6.6	8.8	5.2	10.4	11.8	1.121	9.50	354.0	33.63
October	6.0	9.50	4.2	10.0	10.2	0.990	9.70	306.0	29.68
November	5.6	10.02	3.6	11.0	9.6	0.957	9.96	228.0	22.71
December	5.2	9.50	3.0	11.2	8.2	0.830	10.12	250.0	25.32
January	4.8	9.30	3.0	11.5	7.8	0.791	10.14	242.0	24.52
February	4.5	9.60	3.0	11.0	7.5	0.762	10.16	210.0	21.33
March	3.5	10.25	3.0	10.0	6.5	0.660	10.24	201.0	20.44
April	3.4	9.20	2.8	11.2	6.2	0.627	10.12	180.0	18.21
May	4.5	10.00			4.5	0.450	10.00	139.0	6.18
Totals for eleven months								2,672.0	257.46

TABLE XIII.—*Milk produced by buffalo cow 53. Average fat for seven months, 10.51 per cent.*

[Freshened October 26, 1918. Lactation period not finished.]

Month.	Morning.		Afternoon.		For 24 hours.		Average fat.	Total for month.	
	Milk.	Fat.	Milk.	Fat.	Milk.	Fat.		Milk.	Fat.
	lbs.	*P. ct.*	*lbs.*	*P. ct.*	*lbs.*	*lbs.*	*P. ct.*	*lbs.*	*lbs.*
November	5.8	9.75	4.3	11.6	10.1	1.064	10.05	348.0	34.95
December	5.6	9.40	4.2	12.0	9.8	1.030	10.51	303.8	31.90
January	5.0	9.20	3.8	12.5	8.8	0.935	11.27	272.8	30.74
February	4.7	10.60	3.2	12.6	7.9	0.901	11.40	221.2	25.21
March	4.5	10.25	2.8	11.0	7.3	0.769	10.53	226.3	23.85
April	4.0	10.00	2.5	11.2	6.5	0.680	10.46	195.0	20.40
May	3.0	9.75	2.6	11.0	6.1	0.625	10.24	189.0	19.35
Totals for seven months								1,756.1	186.40

Like most milk, buffalo milk has little or no odor. The strong odor often found associated with it is due to foreign substances, such as hair or flakes of dead skin, that fall into the milk when proper sanitary precautions are not used in milking. When such foreign substances get into the milk, the bacteria that they introduce multiply very rapidly and produce gases with unpleasant odors.

In the College dairy both European and buffalo cows are kept. Buffalo milk is much preferred, because of its richness, by both foreigners (American and European) and Chinese. In

TABLE XIV.—*Milk produced by buffalo cow 54. Average fat for nine months, 12.13 per cent.*

[Freshened September 20, 1918. Lactation period not finished.]

Month.	Morning.		Afternoon.		For 24 hours.		Average fat.	Total for month.	
	Milk.	Fat.	Milk.	Fat.	Milk.	Fat.		Milk.	Fat.
	lbs.	*P. ct.*	*lbs.*	*P. ct.*	*lbs.*	*lbs.*	*P. ct.*	*lbs.*	*lbs.*
September	6.2	10.0	4.6	11.5	10.8	1.199	11.11	97.2	10.79
October	6.5	10.4	4.8	11.4	11.3	1.223	10.83	339.0	36.71
November	6.1	10.2	5.0	11.6	11.1	1.177	11.61	333.0	38.66
December	5.5	11.0	4.0	12.5	9.5	1.105	11.63	284.5	33.09
January	5.4	11.3	3.8	13.0	9.2	1.088	11.82	285.2	33.70
February	5.0	11.0	3.4	13.5	8.4	1.009	12.00	235.2	27.22
March	4.5	10.7	3.7	14.8	8.2	1.029	12.44	254.2	31.62
April	4.4	11.8	2.7	12.0	7.1	0.843	11.89	213.0	25.22
May	3.0	13.0	3.5	13.0	6.5	0.825	13.00	201.0	26.16
Totals for nine months								2,242.3	263.10

TABLE XV.—*Milk produced by buffalo cow 55. Average fat for lactation period, 11.86 per cent.*

[Freshened September 20, 1916. Lactation period finished May 31, 1919.]

Month.	Morning.		Afternoon.		For 24 hours.		Average fat.	Total for month.	
	Milk.	Fat.	Milk.	Fat.	Milk.	Fat.		Milk.	Fat.
	lbs.	*P. ct.*	*lbs.*	*P. ct.*	*lbs.*	*lbs.*	*P. ct.*	*lbs.*	*lbs.*
September	6.3	10.0	4.0	12.3	10.3	1.122	10.89	103.0	11.22
October	5.8	9.8	4.2	12.5	10.0	1.093	10.88	300.0	30.00
November	5.3	10.2	4.0	13.0	9.3	1.060	11.40	279.0	31.80
December	5.0	11.5	3.8	13.5	8.8	1.090	12.38	273.8	33.87
January	4.6	11.0	3.5	13.8	8.1	0.988	12.20	251.0	30.62
February	4.5	11.4	3.0	14.0	7.5	0.933	12.44	210.0	26.34
March	3.3	11.0	2.5	14.60	5.8	0.728	12.54	160.0	20.06
April	3.6	11.5	2.0	14.5	5.6	0.704	12.60	168.0	21.17
May	2.0	13.0	1.5	14.75	3.5	0.482	13.40	108.5	14.53
Totals for lactation period								1,863.3	219.61

modifying milk for infants requiring modified milk, the college physicians prefer buffalo milk to European cows' milk because of the ease with which it lends itself to modification. The usual formula for modification is 100 grams of buffalo milk, 18 grams of sugar, and enough boiled or distilled water to make 300 grams. This makes the percentages of fat, proteins, sugar, and ash about right for infants, as when thus modified the milk compares well with human milk. For children of 3 years or more the milk is usually simply thinned by adding an equal amount of water.

FEED FOR DAIRY COWS

The commonest concentrates fed are equal proportions of a cheap grade of rice chop and wheat bran, fed twice a day. Native cattle are grazed on the public grave and hill land during the daytime. Green grass is cut daily for the European cows, which are kept stabled all day. Most of the grass is cut from

TABLE XVI.—*Milk produced by buffalo cow 60. Average fat for six months, 11.20 per cent.*

[Freshened December 1, 1918. Lactation period not finished.]

Month.	Morning.		Afternoon.		For 24 hours.		Average fat.	Total for month.	
	Milk.	Fat.	Milk.	Fat.	Milk.	Fat.		Milk.	Fat.
	lbs.	*P. ct.*	*lbs.*	*P. ct.*	*lbs.*	*lbs.*	*P. ct.*	*lbs.*	*lbs.*
December	6.2	9.50	4.2	11.75	10.4	1.381	11.35	322.4	36.59
January	6.0	10.20	4.0	12.00	10.0	1.092	10.92	310.0	33.85
February	5.8	10.50	4.0	12.40	9.8	1.105	11.27	274.4	30.90
March	4.8	9.25	3.0	13.00	7.8	0.934	11.97	242.8	28.74
April	4.0	9.50	2.0	11.50	6.0	0.610	10.16	180.0	18.19
May	3.5	10.00	3.0	10.00	6.5	0.650	10.00	201.5	20.15
Totals for six months								1,531.1	168.42

TABLE XVII.—*Milk produced by buffalo cow 63. Average fat for six months, 10.38 per cent.*

[Freshened December 10, 1918. Lactation period not finished.]

Month.	Morning.		Afternoon.		For 24 hours.		Average fat.	Total for month.	
	Milk.	Fat.	Milk.	Fat.	Milk.	Fat.		Milk.	Fat.
	lbs.	*P. ct.*	*lbs.*	*P. ct.*	*lbs.*	*lbs.*	*P. ct.*	*lbs.*	*lbs.*
December	5.0	9.8	4.6	11.2	9.6	0.965	10.05	201.6	19.35
January	5.8	9.6	4.3	11.4	10.1	1.046	10.45	313.0	32.71
February	6.0	9.7	4.2	11.6	10.2	1.069	10.48	283.6	28.97
March	5.5	9.8	4.5	11.25	10.0	1.045	10.45	310.0	31.89
April	4.8	10.0	4.0	11.5	8.9	0.940	10.56	267.0	28.19
May	6.5	10.75	3.0	12.0	8.5	1.059	11.26	263.5	29.66
Totals for six months								1,638.7	170.23

TABLE XVIII.—*Analyses of buffalo milk produced in southern China compared with that produced in other countries.*

[Numbers give percentages.]

	Southern China.	India.[a]	Philippine Islands.[b]	Italy.[a]
Fat	12.60	7.95	6.84	7.99
Protein	6.04	4.00	4.97	4.13
Sugar	3.70	5.18	5.16	4.75
Ash	0.86	0.78	0.83	0.97
Water	76.80	82.09	82.20	82.16

[a] Bailey's Cyclopedia of American Agriculture 3 (1908) 295.

[b] Philippine Agriculturalist and Forester 6 (1917) 110.

NOTE.—Attention may be called to the results recorded by Dovey, Philip. Journ. Sci., § A 8 (1913) 153–155, showing the constituents of nineteen "authentic samples of pure carabao's milk." Only two of these show less than 7 per cent fat while four show more than 12.60 per cent.—EDITORS.

the canal banks. Some of the more progressive dairies are beginning to grow guinea grass, which does very well on the hillsides in this region. When well fertilized with manure from the barns this grass produces a crop from 18 to 24 inches high every two to three weeks throughout the rainy season, from April to September. Dry rice straw is also fed.

COMMON DISEASES

Rinderpest and tick fever are the principal diseases to which cattle are subject. Prof. C. W. Howard, of the biology department of Canton Christian College, says that the latter is caused by the same organism (*Piroplasma bigeninum*) and transmitted by the same tick (*Boophilus annulatus*) as in the Southern States of the United States. Both the buffalo and the native yellow cow are largely immune to the fever, while the European cows quickly succumb to the disease when exposed to it. However, European calves born here readily become immune. Rinderpest causes heavy losses, especially among buffaloes and European cattle, during the months of March and April. The Hongkong Dairy Farm has had outbreaks of rinderpest among European cattle every year for the past five or six years. The use of rinderpest serum has checked the disease in every outbreak. It is interesting to note that the Chinese dairies have suffered very little from rinderpest in their herds of European cattle, although in most cases their methods of caring for the cows are not very sanitary.

According to Dr. C. M. Heanley, of the Hongkong Vaccine and Bacteriology Laboratory, tuberculosis is practically unknown among the native cattle of southern China, occurring once in 250,000 head and then only when the animals are closely stabled with European cattle. Dr. A. Gibson, colonial veterinarian, Victoria, Hongkong, tells me that he has seen but two cases of tuberculosis among native cattle, during the thirteen years that he has held his present position. These two cases were in bullocks. He has never seen tuberculosis in the Chinese water buffalo.

My measurements of twelve buffalo cows, in the college dairy, May 20, 1919, are given in Table XIX. These twelve cows are typical of the buffalo in southern China.

TABLE XIX.—*Measurements of twelve buffalo cows, in the Canton Christian College dairy.*

[Numbers give centimeters.]

Cow No.	Length.		Height.			Chest girth.	Body.		Loin; width.
	Tip of nose to buttocks.	Top of shoulders to hips.	At withers.	At croup.	At lowest point of back.		Girth at navel.	Depth at navel.	
51	223.0	75.0	120.0	124.5	117.0	221.0	249.0	77.5	38.0
52	225.0	87.0	122.0	124.0	119.0	205.0	249.0	79.0	41.0
53	218.0	73.0	120.0	120.0	116.0	193.0	237.0	74.5	39.0
54	226.0	85.0	125.0	130.0	122.0	205.0	236.0	84.0	36.5
55	228.0	70.0	125.0	125.5	121.0	209.0	248.5	76.5	38.0
56	214.0	70.0	120.0	117.5	113.5	194.0	227.7	66.5	32.0
57	244.0	81.0	225.5	124.0	122.0	204.5	255.5	77.0	40.0
58	236.0	79.0	121.5	120.0	118.0	199.5	237.2	68.0	38.0
59	230.0	76.5	117.0	117.0	114.0	189.0	226.0	71.0	33.5
60	229.0	80.0	120.0	117.5	131.2	191.0	245.0	72.0	37.5
61	240.0	80.0	124.5	128.0	124.0	206.4	245.0	80.0	37.5
62	270.0	79.0	126.5	122.0	124.0	202.0	245.0	85.0	38.0

Cow No.	Hips; width.	Underline; length.	Chest between legs; width.	Length of head; top of poll to end of nose.	Face; width at eyes.	Muzzle; width.	Horns.		
							Length, outside curve.	Diameter at base.	Spread, widest point.
51	52.0	76.0	27.0	49.0	22.0	20.0	54.0	12.0	66.5
52	54.5	77.0	25.0	46.0	22.0	21.0	60.0	11.0	60.0
53	56.0	82.5	21.0	55.5	22.0	20.5	62.0	8.5	69.0
54	53.2	74.0	23.0	50.0	20.7	17.8	48.2	8.5	53.8
55	56.0	70.0	24.0	49.0	21.0	16.5	53.3	7.8	68.0
56	49.0	76.0	22.0	46.0	22.5	16.5	56.5	8.0	56.6
57	57.0	85.0	26.6	50.5	21.2	18.0	52.0	8.5	38.2
58	54.0	85.0	23.5	48.0	20.5	19.5	54.5	7.6	64.5
59	52.0	76.0	22.0	47.5	20.5	17.0	59.0	9.5	83.5
60	52.0	76.5	25.5	49.5	22.2	16.0	65.1	8.5	54.0
61	58.5	66.0	24.0	50.0	23.0	18.0	54.6	9.5	53.0
62	54.0	73.0	29.0	50.0	22.0	16.0	52.0	9.0	72.5

TABLE XIX.—*Measurements of twelve buffalo cows, in the Canton Christian College dairy*—Continued.

Cow No.	Distance between tips of horns.	Neck; from back of poll to top of shoulders.	Neck; throat to front of sternum.	Upper arm; point of shoulder to center of elbow.	Lower arm; elbow to center of knee.	Lower thigh; center of stifle to center of hock.	Foreshank; center of knee to center of pastern.	Rear shank; center of knee to center of pastern joint.	Width of—	
									Forehoof.	Rear hoof.
51	62.0	62.0	42.0	38.0	40.0	41.0	18.0	35.0	14.0	12.0
52	51.0	64.0	40.0	35.0	37.0	40.0	18.5	30.0	13.5	12.5
53	63.5	58.5	45.5	36.0	38.0	39.0	21.5	26.0	13.0	13.0
54	54.6	64.0	42.5	36.4	37.0	42.0	20.3	35.0	13.2	11.0
55	53.5	79.0	49.5	35.0	33.0	40.5	19.0	33.0	14.5	12.0
56	49.8	55.5	45.5	33.0	30.5	30.8	19.3	31.0	13.8	12.0
57	20.5	77.0	42.0	37.0	34.0	43.0	20.1	33.0	14.0	12.0
58	62.0	61.0	38.5	38.0	34.0	37.5	21.0	30.5	13.5	12.0
59	33.5	59.5	48.5	35.0	34.5	30.5	18.5	32.5	14.0	11.5
60	36.0	64.0	44.0	37.0	34.0	38.0	20.0	31.6	13.0	12.0
61	45.0	72.5	42.0	36.0	34.6	43.0	21.5	33.0	14.5	12.0
62	72.5	62.0	54.0	40.0	38.0	43.0	23.0	36.0	12.6	11.4

Cow No.	Length of—		Circumference of—						Distance from—	
	Forehoof.	Rear hoof.	Knee.	Hoof.	Foreshank.	Rear shank.	Forepastern.	Rear pastern.	Forelegs to floor of chest.	Hind legs to flank.
51	14.0	14.0	31.0	45.0	21.5	23.9	27.0	26.5	48.0	63.0
52	16.0	14.0	32.0	42.0	22.0	22.5	28.5	28.0	51.0	60.5
53	15.0	14.0	31.5	42.5	22.0	23.6	26.2	26.8	48.0	60.5
54	15.4	13.0	31.5	42.0	21.0	21.6	27.2	25.8	48.0	62.0
55	15.2	14.0	31.2	40.5	20.5	20.3	27.5	26.5	58.0	61.7
56	14.0	13.0	30.0	37.5	20.0	20.5	25.5	23.5	45.5	55.4
57	15.0	13.0	32.5	43.6	21.8	21.5	31.5	29.0	52.0	65.5
58	14.0	13.2	33.0	42.5	20.5	21.1	27.10	27.4	44.5	59.0
59	13.5	12.4	30.0	38.5	19.5	21.0	26.8	29.0	40.7	56.2
60	14.0	12.0	33.0	42.5	23.0	22.0	28.0	27.7	53.3	59.5
61	16.0	15.0	34.0	37.0	21.5	22.7	28.2	28.0	48.0	63.0
62	16.0	15.0	34.1	40.0	22.1	29.5	29.5	26.9	53.0	67.0

ILLUSTRATIONS

PLATE I

FIG. 1. Native yellow cattle of China, grazing on the cemetery hills north of Canton, China.
2. Water buffaloes, in Canton Christian College dairy.
3. Water buffaloes, in Canton Christian College dairy.

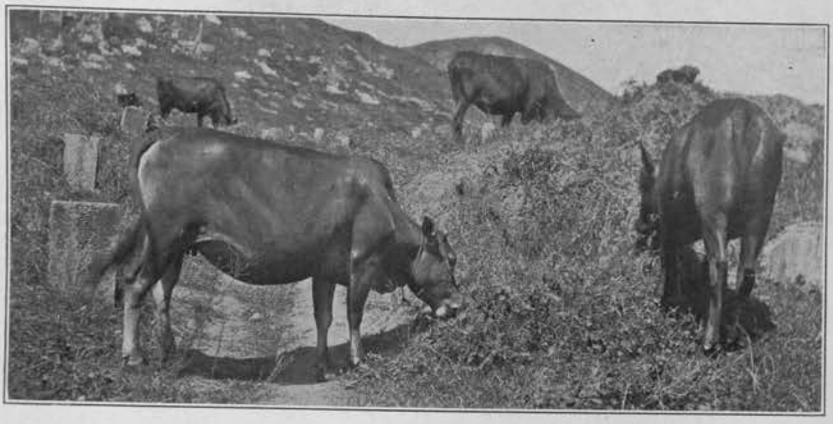

Fig. 1. Native yellow cattle of China.

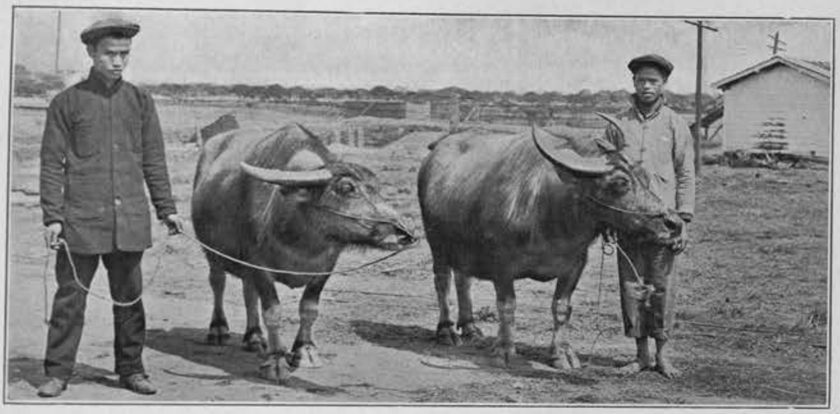

Fig. 2. Water buffaloes.

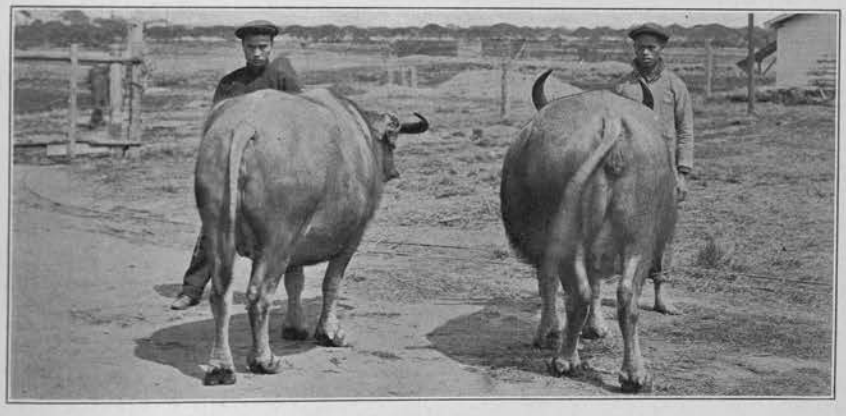

Fig. 3. Water buffaloes.

PLATE I.

THE ANALYSIS OF PORTLAND CEMENT RAW MIXTURE [1]

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TWO TEXT FIGURES

Analyses of a cement raw mixture by several methods failed to give conformatory results. Each of these methods was studied with the object of increasing the accuracy, lessening the time required, and discovering the sources of error. Little has been written on the analysis of raw mixtures, and still less concerning the sources of error, especially when indirect methods for determining the calcium carbonate content are followed. Though the mixture here discussed doubtless presents more analytical difficulties than the average, work with it has pointed out several factors that affect the results obtained with this class of materials.

When a cement plant is past the experimental stage and is in regular operation, complete analyses of the raw materials or of the raw mixture are, as a rule, required only occasionally. The proportioning of the mixture is usually based on the percentage of calcium carbonate, which is the most important constituent. This determination must be made repeatedly; its frequency at a given plant depending on a number of factors, such as the character of the raw materials, the arrangement of the machinery, and the like. As with other manufacturing processes, it is desirable to find a method of analysis that will give results within the required limits of accuracy, in the shortest time. The methods available may be divided into two classes; namely, those in which the calcium itself is determined and those in which some other constituent is determined. They include the following:

1. By determining calcium and calculating to calcium carbonate.
   - By precipitation with ammonium oxalate.
     - Drying or ignition of precipitate and weighing.
     - Solution of precipitate in acid and titration.
     - Precipitation without complete removal of silica.
     - Precipitation in presence of an organic acid.
   - Other methods for the determination of calcium.

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[1] Received for publication May 26, 1919.

2. By determining some other constituent and calculating to calcium carbonate.
    - By evolution of carbon dioxide.
        - Absorption in soda lime or alkali hydroxide solution.
        - Loss in weight due to evolution of gas from Geissler's or similar apparatus.
        - Loss on ignition.
        - Hydrometer apparatus.
        - Monometer apparatus.
        - Calcimeter.
    - By titration methods.
    - By determining acid-insoluble material.

Determination of calcium by precipitation as calcium oxalate.—Most of the methods depend on the fact that calcium may be precipitated from solutions of its salts by the addition of ammonium oxalate. The solution may be titrated directly with standard oxalate solution,[2] or an excess of oxalate may be added, the precipitate collected and the amount remaining uncombined with the excess oxalate titrated with potassium permanganate.[3] Calcium oxalate may be dried and weighed;[4] may be ignited to the oxide,[5] carbonate,[6] or sulphate;[7] or may be dissolved in sulphuric[8] or in hydrochloric acid,[9] and titrated with potassium permanganate. It may be also determined by the Fox [10] photometric method.[11]

Determination of calcium without the use of ammonium oxalate.—The methods include precipitation as the iodate,[12] the tungstate,[13] the arsenate,[14] and the carbonate.[15] According to Knobloch,[16] calcium may be determined by adding ferric chloride and zinc iodide solutions, and titrating the iodine liberated with sodium thiosulphate. A neutral solution of a calcium salt may be titrated with standard sodium carbonate solution.[17]

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[2] Prunier, Journ. Chem. Soc. 48 A2 (1885) 296.

[3] Kraut, Chem. Centralbl. 1 (1856) 316.

[4] Fresenius, C. R., Quantitative Chemical Analysis. New York, John Wiley and Sons 1 (1904) 272.

[5] Fritzshe, Zeitschr. f. Anal. Chem. 3 (1864) 179.

[6] Fresenius, op. cit. 273.

[7] Fresenius, op. cit. 272.

[8] Mohr, Titrirmethode, ed. 7, 239.

[9] Peters, C. A., Am. Journ. Sci. 12 (1901) 216.

[10] Hines, J. I. D., Journ. Am. Chem. Soc. 22 (1900) 269.

[11] For other comments on methods involving the use of ammonium oxalate, see Young, R. F., and Baker, B. F., Chem. News 86 (1902) 148, and Pagireff, W., Journ. Chem. Soc., 82 A2 (1902) 356.

[12] Sonstadt, E., Chem. News 29 (1874) 209.

[13] Saint-Sernin, A., Compt. Rend. 156 (1913) 1019.

[14] Fox, P. J., Journ. Ind. Eng. Chem. 5 (1913) 910.

[15] Forte, O., Journ. Chem. Soc. 66 A2 (1894) 322.

[16] Knobloch, J., Journ. Chem. Soc. 68 A2 (1895) 326.

Determination of constituents other than calcium.—Since the calcium in a cement mixture is usually largely present as the carbonate, the carbon dioxide evolved on ignition, or on treating with acid, is often made the basis for determining the calcium carbonate content. The following are among the many methods that may be used:

The gas may be absorbed in soda lime or in an alkali hydroxide solution,[18] and the resulting mixture either weighed or titrated with standard acid. The weight of the carbon dioxide evolved may be found by the use of any one of a number of apparatus such as Geissler's,[19] or by weighing the sample before and after ignition.[20] Barker [21] has designed a special form of hydrometer in which the sample is placed and treated with hydrochloric acid. The decrease in weight due to the evolution of carbon dioxide is shown by the position of the apparatus in the water in which it floats. Chapin [22] calculates the volume of the evolved gas from the increase in pressure in a closed vessel, as indicated by a monometer. The volume of evolved gas is frequently measured in a gas burette, or some type of calcimeter [23] is employed.

A method of a different type consists in treating the sample with standard acid and, when the reaction is complete, titrating the excess acid with standard alkali. The details of this method differ in various laboratories.[24] In some cases the calcium carbonate content may be estimated from the acid-insoluble matter.[25]

The United States Government official method for the determination of calcium in raw mixtures specifies that the sample be ignited over a blast lamp for fifteen minutes and then treated with hydrochloric acid.[26] The silica is dehydrated and filtered out. The iron and the aluminium are removed by precipitating twice with ammonium hydroxide. The determination is completed as follows:[27]

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[17] Vizern, Journ. Chem. Soc. 66 A2 (1894) 161.

[18] Fresenius, C. R., Zeitschr. f. Anal. Chem. 2 (1863) 49, 341.

[19] Journ. f. Prak. Chem. 60 (1853) 35.

[20] Treadwell and Hall, Analytical Chemistry. New York, John Wiley and Sons 2 (1907) 292.

[21] Barker, J. F., Journ. Ind. Eng. Chem. 9 (1917) 786.

[22] Chapin, W. H., Journ. Ind. Eng. Chem. 10 (1918) 527.

[23] For description of the Scheibler-Dietrich calcimeter see George Lunge, Technical Methods of Chemical Analysis. New York, D. van Nostrand Co. 1 (1908) 659.

[24] Kluge, F., Chem. Zeitg. 20 (1896) 372; Meade, R. K., Portland Cement. The Chemical Publishing Co., Easton, Pa. (1911) 313.

[25] Meade, op. cit. 326.

[26] If anything remains undecomposed it is separated, fused with sodium carbonate, dissolved, and added to the original solution.

> To the combined filtrate from the $Al_2O_3 + Fe_2O_3$ precipitate a few drops of NH_4OH are added, and the solution brought to boiling. To the boiling solution 20 cc of a saturated solution of ammonium oxalate is added, and the boiling continued until the precipitated CaC_2O_4 assumes a well-defined granular form. It is then allowed to stand for 20 minutes, or until the precipitate has settled, and then filtered and washed. The precipitate and filter are placed wet in a platinum crucible, and the paper is burned off over a small flame of a Bunsen burner. It is then ignited, redissolved in HCl, and the solution made up to 100 cc with water. Ammonia is added in slight excess, and the liquid is boiled. If a small amount of Al_2O_3 separates this is filtered out, weighed, and the amount added to that found in the first determination, when greater accuracy is desired. The lime is then reprecipitated by ammonium oxalate, allowed to stand until settled, filtered and washed,[28] weighed as oxide after ignition and blasted in a covered crucible to constant weight, or determined with dilute standard permanganate.[29]

Although the procedure given the preference in the official method (igniting the precipitate and weighing the oxide) is subject to several sources of error, such as the solubility of the oxalate in water,[30] the possible contamination of the precipitate,[31] the absorption of moisture during weighing, and the like, it is generally conceded to be the most accurate method known at present. Its principal disadvantage in commercial work is the time required. According to the original report, it takes almost seven hours to run a sample of raw mixture to the completion of the calcium determination, and the time required to obtain the result can be only slightly shortened by omitting the completion of the silica, iron, and aluminium determinations. Only a few minutes for each sample may be saved by substituting the titration method, if all the separations are made as specified.

In connection with the titration method, however, several modifications have been developed which shorten the time, though they have some effect on the accuracy of the results. One such modification is to precipitate and reprecipitate the iron and aluminium from hydrochloric acid solution without first removing the silica. The calcium in the filtrate is precipitated once as the oxalate, and the precipitate is titrated with permanganate.[32]

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[27] From Method suggested for the analysis of limestones, raw mixtures, and Portland cement by the committee on uniformity in technical analysis with the advice of W. F. Hillebrand, *Cir. U. S. Bur. Standards* 33 (1912) 15. For the original report of this committee, see Journ. Soc. Chem. Ind. 21 (1902) 12-30.

[28] The volume of wash water should not be too large; vide Hillebrand. *United States Geological Survey, Bull. 422, p. 119.* [Footnote in original.]

[29] The accuracy of this method admits of criticism, but its convenience and rapidity demand its insertion. [Footnote in original.]

[30] See also Peters, C. A., loc. cit.

[31] Täubner, H., Chem. Zeitg. 26 (1902) 246.

The method may be still further shortened by neutralizing the original hydrochloric acid solution with ammonia and adding some organic acid in which calcium oxalate is not appreciably soluble. The calcium may be precipitated as oxalate without the removal of iron and aluminium. The calcium oxalate is filtered out, and the determination is completed in the regular manner. Citric,[33] tartaric,[34] and oxalic[35] acid have been used.

Of the methods noted above, several are used extensively for controlling the calcium carbonate content of raw mixtures in cement plants. These include some modification of the determination of calcium by precipitation with ammonium oxalate and titration with permanganate, the determination of carbon dioxide with the calcimeter, the determination of total alkalinity by titration with standard acid and alkali, and the determination of acid-insoluble matter. The last named is used much less frequently than the others. The procedure in each case that I have found best suited to the raw mixture discussed in this paper is as follows:

In determining the calcium, the usual method of igniting the raw mixture before adding hydrochloric acid at the beginning of an analysis is not sufficient.[36] Results are the same either with or without ignition, but almost 2 per cent too low. It is necessary to fuse with sodium carbonate. To avoid one filtration, the whole sample is fused instead of simply the acid-insoluble residue. The melt is dissolved in hydrochloric acid and the iron and the aluminium are removed by twice precipitating with ammonia. The calcium in the filtrate is precipitated once with ammonium oxalate, and the precipitate is dissolved in dilute sulphuric acid and titrated with permanganate. The titration method has been found more satisfactory than ignition, for use in the Tropics. The high humidity of the atmosphere renders it difficult to weigh calcium oxide in an ordinary platinum crucible without absorption of moisture. Results obtained with the method just described have been found to compare favorably with those of the official method; consequently it was adopted as standard for the present work.

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[32] Enright, B., Journ. Am. Chem. Soc. 26 (1904) 1003.

[33] Passon, Max, Zeitschr. f. Ang. Chem. (1898) 776.

[34] Blum, L., Zeitschr. f. Anal. Chem. 39 (1900) 152.

[35] Meade, R. K., Chem. Eng. 1 (1904) 21.

[36] With reference to igniting the sample, W. F. Hillebrand, Journ. Soc. Chem. Ind. 21 (1902) 25, says: "Whether all cement mixtures can be thus rendered wholly soluble I am unable to say, but doubtless most of them can be, and if so, this method should always be resorted to in order to avoid the use of alkali carbonates."

In making a calcimeter determination, the sample is treated with hydrochloric acid (density, 1.125), and the calcium carbonate content is calculated from the volume of carbon dioxide evolved. In some laboratories the amount of sample taken is not kept constant, but tables are used which indicate the weight that corresponds to the observed temperature and pressure. When this amount is placed in the appparatus, no reduction of the observed volume to standard conditions is necessary. However, this arrangement has certain disadvantages when used in routine work. The continual changing of weights becomes tiresome and the average routine analyst is likely to make mistakes, especially at night. Also, if for any reason it is desired to make a number of determinations at one time, the samples cannot all be weighed at once because the temperature or the pressure may change before the work has been completed and thus render the results incorrect. Also, if the apparatus was standardized at a given temperature and pressure with Iceland spar, the result could not be applied to a determination made after these conditions had changed without giving rise to error.

The method used in connection with this work has proved more satisfactory. A standard raw mixture is prepared, having as nearly as possible the ideal composition of the regular mixture. This is prepared in quantities sufficient to last for a month or two and is analyzed in triplicate for calcium by the potassium permanganate titration method. At the beginning of his day's work the analyst records the temperature and pressure, weighs out an equal amount of the standard and of his first sample to be tested, and places them successively in the calcimeter. As long as the temperature and the pressure remain the same, it is not necessary to use another portion of the standard; but, if either changes, a new standard must be weighed and analyzed with the next routine sample. If during the course of the day they both return to former values, the result of the standard at that temperature and pressure may be used.

Since with each determination conditions are the same for both standard and sample, the calcium carbonate content of the sample may be directly calculated from the known content of the standard by proportion. A table for making these calculations covering the usual range of results for both the standard and the sample may be easily prepared. Errors, such as those due to absorption of carbon dioxide in the hydrochloric acid, lack of accuracy in either thermometer or barometer, and the like, are thus automatically corrected. Everything considered, the labor required by this procedure is no greater than that required by the other, and the results are more satisfactory. When the sample contains considerably more silicate than the standard there will be an error in the result, the reason for which is explained in this paper. It has been proposed to correct this by preparing a series of standards ranging from the lowest to the highest calcium content likely to be found in a sample, and then, for a given determination, using the standard nearest that sample in composition. This would be an improvement, but it is doubtful if the increased labor would be justified.

In the acid–alkali titration method, the sample is placed in a 300-cubic centimeter Erlenmeyer flask, fitted with a rubber stopper bearing a vertical glass tube as a condenser. A measured amount of 0.4 *N* hydrochloric acid is added, and brought just to a boil over a Bunsen burner. The solution is cooled, diluted to from 100 to 150 cubic centimeters, and titrated with standard sodium hydroxide of the same concentration, using methyl orange as the indicator. Of the several concentrations of acid tried, 0.4 *N* was the lowest that would dissolve nearly all the sample without the application of heat. However, that solution was not quite complete without warming. Methyl orange is preferred to phenolphthalein, although the end point is more difficult to see. It is not necessary to remove the carbonates in preparing the standard sodium hydroxide solution (as should be done if phenolphthalein is to be used), and it is not necessary to boil the acid after the sample is dissolved, to remove the carbon dioxide.

The method for determining acid-insoluble matter is the same as the one given by Meade, except that hydrochloric acid having a density of 1.125 is used. The sample is treated with this acid, and the mixture is boiled several minutes. The insoluble matter is then collected, washed, ignited, and weighed.

The raw mixture with which this paper is concerned is made from three materials; namely, a hard limestone, and two siliceous materials that are designated silicate 1 and silicate 2. The analyses of these materials are shown in Table I.

TABLE I.—*Analyses of raw materials.*

[Numbers give percentages.]

	Limestone.	Silicate.	
		1.	2.
Loss on ignition	42.86	5.77	3.24
Silica (SiO_2)	0.68	53.76	61.35
Iron oxide (Fe_2O_3)	0.30	6.84	4.82
Aluminium oxide (Al_2O_3)	0.34	22.88	18.46
Calcium oxide (CaO)	54.72	5.41	5.22
Magnesium oxide (MgO)	0.56	1.88	2.72
Sodium oxide (Na_2O)	0.60	1.65	2.26
Potassium oxide (K_2O)	trace	1.84	1.95
Sulphuric anhydride (SO_3)	trace	trace	trace

On analyzing a number of samples by the four methods mentioned above and calculating all results to percentage calcium carbonate, the agreement was not satisfactory. The analyses of ten samples are shown in Table II. Most of these were prepared in the laboratory from samples of the raw materials, dried and ground to pass a 200-mesh sieve. These are only a few of many comparative analyses that have been made from time to time.

TABLE II.—*The analyses of raw mix by several methods.*

[Numbers give percentages.]

Sample No.	By titration with potassium permanganate. Total calcium is calculated to calcium carbonate.	By calcimeter. Total carbon dioxide is calculated to calcium carbonate.	By acid-alkali titration. Total alkalinity is calculated to calcium carbonate.	Matter insoluble in hydrochloric acid with density of 1.125.
1	54.40	51.25	53.03	22.30
2	62.30	59.42	61.31	17.25
3	66.50	64.00	65.35	16.10
4	76.80	76.00	76.26	11.20
5	77.80	77.25	76.30	21.68
6	78.00	77.00	76.30	21.82
7	79.60	78.63	78.88	11.04
8	83.00	83.08	81.71	8.10
9	84.40	84.17	83.22	7.00
10	86.50	86.00	85.14	6.70

CAUSES OF ERROR

In any analytical procedure certain errors of the process itself—such as inexact calibration of apparatus, slight solubility of precipitates, difficulty of complete washing, and the like—cannot be eliminated. There is another class of errors due to the composition of the substances under investigation; errors of this class have been found to be largely responsible for the nonconcordant results of Table II.

In the first column, the calcium is determined, and the results are calculated to calcium carbonate. In the case of the calcimeter or with any other method in which the carbon dioxide is determined, the result in terms of calcium carbonate must be calculated from the total carbon dioxide found. This, of course, assumes that all calcium is present as carbonate and that all carbon dioxide is combined with calcium, which in this case is not true. Carbonates other than calcium are present in small amount in the limestone, causing the results to be slightly too high. However, the calcium in the two siliceous materials is not present as carbonate and consequently is not included when the determination by calcimeter is made. The net result is that the values obtained are low.

In the acid–alkali titration method, the alkalinity or acid-consuming power is calculated to calcium carbonate. In this case the errors due to apparatus and to manipulation may be made very small. However, there are much greater errors due to the composition of the mixture. On being treated with standard acid, all carbonates go into solution and are calculated to calcium carbonate. Of the calcium in the siliceous materials, a portion goes into solution without neutralizing acid equivalent to that which would be required for calcium carbonate, and a portion is undissolved by the acid. Some of the iron and the aluminium in these materials go into solution and consequently neutralize the acid, thereby tending to produce a higher result.[37]

The results obtained by determining the acid-insoluble matter were so irregular that no further analyses by that method were made.

Slight errors are caused by the presence of moisture in the raw mixture as it comes from the tube mill. It has not been found practicable to eliminate these in the routine work. The moisture content of the material as it enters the tube mill is determined at regular intervals and is kept as low as possible under the prevailing conditions at the plant. It is not practical to dry each sample before analysis, because the results cannot be obtained as rapidly as they are needed. The limestone as it comes from the quarry is frequently contaminated to a greater or less extent with clay different in composition and in analytical behavior from the two siliceous materials regularly used in making the mix. The results obtained by testing the three raw materials by the calcimeter and the alkali-acid titration method are shown in Table III.

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[37] S. B. Newberry, Cem. and Eng. News, March (1903) 35, describes a double titration method by which correction for magnesium may be made. With the raw mixture under investigation, however, the error due to the effect of iron and aluminium cannot be corrected. The error due to magnesium is not corrected because it tends to compensate the other one.

TABLE III.—*Partial analyses of the three raw materials by different methods.*

Calcium carbonate.	Limestone.	Silicate.	
		1.	2.
	Per cent.	*Per cent.*	*Per cent.*
By calcimeter (total CO_2 calculated to $CaCO_3$)	94.50	0.00	0.00
By titration (total acid neutralized calculated to $CaCO_3$)	95.40	2.60	3.30

It will be noted that although the two silicates contain considerable calcium there is no evolution of gas when they are treated with acid. However, although they contain no carbonates, they have acid-consuming values equivalent to 2.60 per cent and 3.30 per cent calcium carbonate, respectively. The portion of each, soluble in 0.4 *N* hydrochloric acid, gives the results shown in Table IV, calculated to the basis of the original sample.

TABLE IV.—*Constituents of the two silicates.*

	Silicate.	
	1.	2.
	Per cent.	*Per cent.*
Iron and aluminium oxides	2.57	6.65
Calcium oxide (calculated to $CaCO_3$)	2.26	3.08

The sources of error with the analytical methods employed and their effect on the results are illustrated in fig. 1. This is based on the typical analysis shown in Table V.

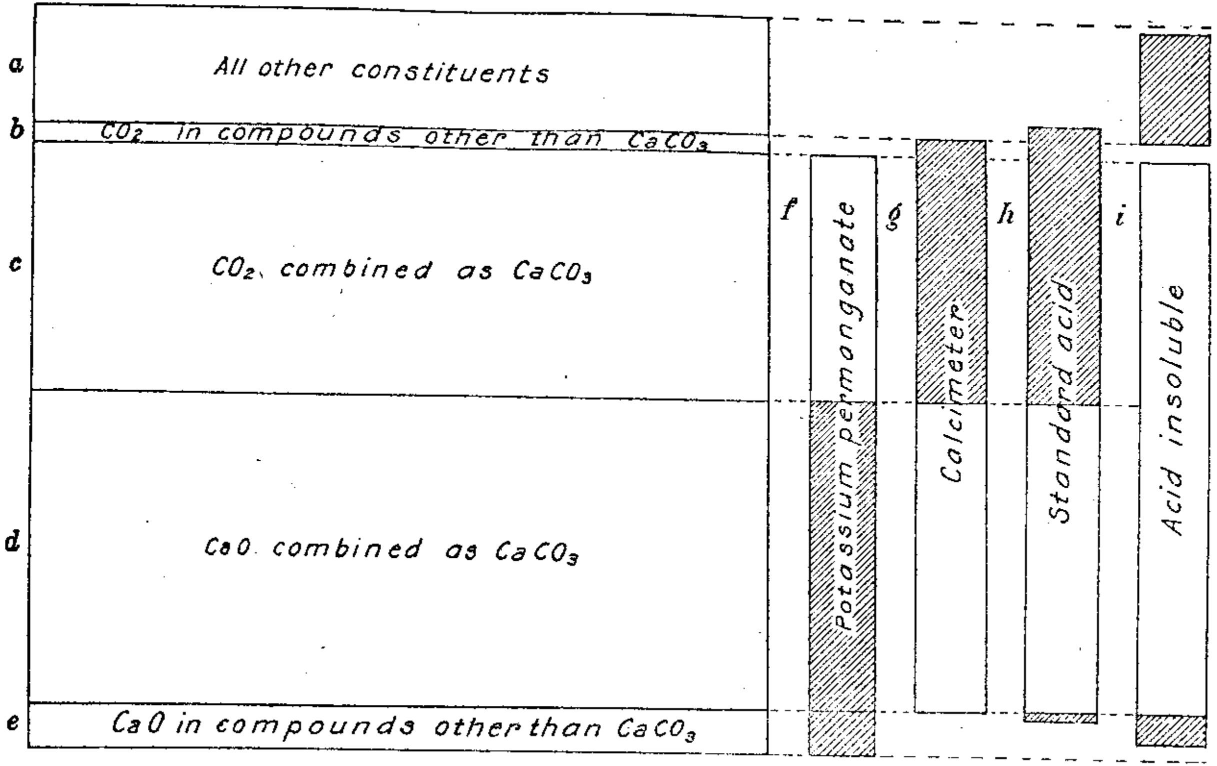

FIG. 1. Showing composition of raw mixture and some causes for nonagreement of results by several methods. Areas *c* and *d* are drawn to scale, but *b* and *e* are exaggerated by 5 for the sake of clearness, thereby making *a* proportionately smaller.

TABLE V.—*Typical analysis.*

Constituent.		Equivalent to calcium carbonate.
	Per cent.	*Per cent.*
Calcium oxide combined as calcium carbonate	42.08	75.05
Calcium oxide in other compounds	1.23	2.19
Carbon dioxide combined as calcium carbonate	32.99	75.05
Carbon dioxide in other compounds	0.46	1.37
All other constituents	23.24	-------
Acid-soluble portions of silicate	-------	0.65

The square represents the composition of a sample of raw mixture having the analysis given in Table V. The calcium oxide combined as calcium carbonate and the carbon dioxide combined as calcium carbonate are drawn to scale. The calcium oxide and the carbon dioxide in compounds other than calcium carbonate are exaggerated five times to make them more easily seen on the diagram, and the rectangle representing all other constituents is made proportionally smaller. The rectangles *f*, *g*, *h*, and *i* at the right of the square represent the results that would be obtained by analyzing the sample by four different methods. The shaded portion of each rectangle shows the constituents on which the result is based, and the total area (except in *i*) shows the calcium carbonate content as calculated from this result. In *f* the total calcium, in whatever way combined, is determined and calculated to calcium carbonate. This is taken as correct, since we are concerned only with the calcium present and not with the carbon dioxide. In *g* the total carbon dioxide, in whatever way combined, is determined and calculated to calcium carbonate. With respect to the carbon dioxide, the result is slightly too high, because it includes the carbon dioxide not combined as calcium carbonate. However, the calcium present in the silicates is omitted. In *h* the total carbon dioxide is likewise included; but, in addition, a portion of the calcium and of the iron and aluminium in the siliceous materials have acid-consuming power. Theoretically, the analysis of this sample would be as follows:

	Calcium carbonate.
	Per cent.
By permanganate titration	75.05 + 2.19 = 77.24
By calcimeter	75.05 + 1.37 = 76.42
By acid-alkali titration	75.05 + 1.37 + 0.65 = 77.07

In general, both the calcimeter and the acid–alkali titration results are below the results obtained with potassium permanganate. Due to errors of the apparatus and of the process, however, the calcimeter results are frequently higher than the acid–alkali titration results. Up to the present it has not been found possible to obtain concordant results by any two of the three principal methods investigated, nor to discover a correction formula by which the results obtained by one of the indirect methods could be calculated to those of the direct method. Theoretically the true calcium carbonate content should be given by the formula:

$$\text{Percentage of calcium carbonate} = x + (100 - x)\,k,$$

in which x is the percentage of calcium carbonate found by the calcimeter and k is a constant depending on the amount of calcium in the siliceous materials. However, it may be seen from Table II that, due to irregularities in the composition of the raw materials, the clay contamination of the limestone, and certain phases of the manufacturing process, the constant, k, cannot be calculated with sufficient accuracy to justify the use of the formula.

When cement raw mixture enters a kiln and is gradually converted into clinker, results obtained by indirect methods of analysis are of course no longer applicable and any calculation of the

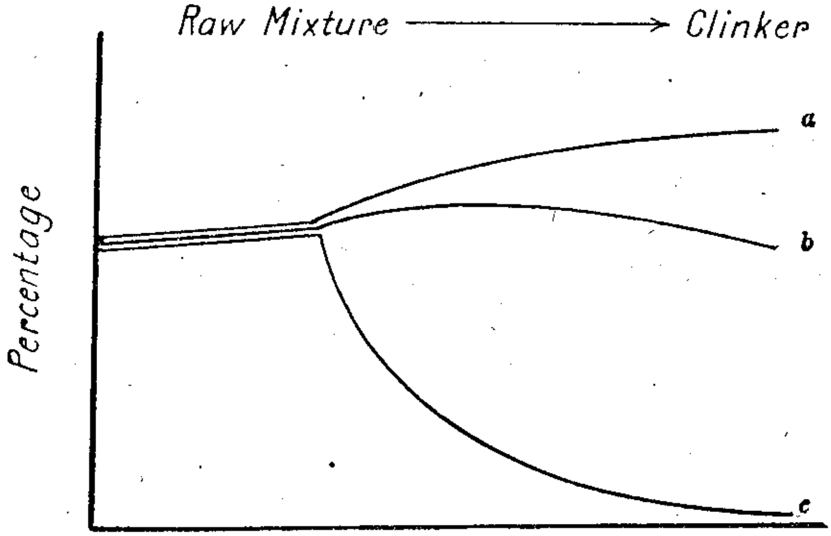

FIG. 2. Analysis of raw mixture at various stages of its conversion into clinker.

calcium present must be based on the determination of the calcium itself. The reason for this is shown in fig. 2, which is based on the analysis of a number of samples of raw mixture at various stages of conversion into clinker. Curve *a* shows total calcium; *b*, total alkalinity; and *c*, carbon dioxide—all calculated to percentage of calcium oxide. The raw mixture as it entered the kiln contained almost 44 per cent calcium oxide as indicated by the three methods of analysis, taking into account the errors, which have been explained.

The first part of all three curves rises, because during the first period no chemical change in the constituents of the mixture is taking place, and the percentage of calcium oxide is increasing because of the loss in moisture, organic matter, and the like. However, the change at once becomes pronounced, when the temperature becomes sufficiently high to decompose the limestone. Due to the loss in weight caused by the evolution of carbon dioxide, the percentage of calcium oxide present continually increases and the percentage of carbon dioxide decreases. The curve representing the alkalinity, or the acid-consuming value, of the mixture does not change so much as the other two. The factors that tend to make the curve rise and those having the reverse effect largely neutralize each other.[38]

SUMMARY

In determining the calcium carbonate content of Portland cement raw mixture the methods available may be divided into two classes; namely, those in which the calcium is determined and those in which some other constituent is determined. Although some methods of the first class have been greatly shortened by several investigators, generally some method of the second class is employed in control work because of simplicity and rapidity. While all methods are subject to errors arising from the apparatus and from the procedure employed, errors due to the nature of the constituents of the raw mixture may greatly influence the results. The causes of errors that may arise have been studied.

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[38] An investigation of certain phases of the subject is now in progress.

ILLUSTRATIONS

TEXT FIGURES

FIG. 1. Diagram, showing composition of raw mixture and some causes for nonagreement of results by several methods. Areas *c* and *d* are drawn to scale, but *b* and *e* are exaggerated by 5 for the sake of clearness, thereby making *a* proportionally smaller.

2. Diagram of analyses of raw mixture at various stages of its conversion into clinker.

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CONTENTS

Page.

COCKERELL, T. D. A. Philippine bees of the genus Nomia 1

COCKERELL, T. D. A. The metallic-colored Halictine bees of the Philippine Islands 9

FUNKHOUSER, W. D. New records and species of Philippine Membracidæ 15

SHUFELDT, R. W. Osteological and other notes on the monkey-eating eagle of the Philippines, Pithecophaga jefferyi Grant 31

UICHANCO, LEOPOLDO B. General facts in the biology of Philippine mound-building termites 59

BAKER, C. F. The Malayan Machærotinæ (Cercopidæ) .. 67

COWLES, R. P. Habits of tropical Crustacea: III 81

LEVINE, C. O. Milk produced in southern China 91

WITT, J. C. The analysis of Portland cement raw mixture 107

REVIEW 123

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